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THE SOUTHWEST PASS BOARD, to report on the improvement of the entrance to the Mississippi River, which was appointed on March 16, is made up as follows: Col. Henry M. Robert and Major George McC. Derby, Corps of Engineers, U. S. A., and Mr. Robert Moore and Mr. William Starling, Mems. Am. Soc. C. E., as civilian members of the board. Under Col. Robert as President, the board is to prepare plans and report upon a project for securing a navigable channel of suitable width and 35 ft. deep at mean low water through the Southwest Pass of the Mississippi River. The South Pass entrance into the Mississippi River is now barely navigable by vessels drawing 23 ft. of water, according to the New Orleans press. A shoal has formed near the head of the pass, and the situation is serious for the commerce of New Orleans and the Mississippi Valley. The New Orleans Board of Trade is petitioning the government to take some immediate action towards maintaining a deeper channel in the South Pass.

NAVIGABLE WATERWAYS IN FRANCE in 1897 carried a total of 30,609,000 tons of freight, of which 13,553,000 tons was carried upon rivers and 17,055,800 tons on canals. How trifling this freight movement is in comparison with American practice may be seen by comparing it with the figures for American railway freight traffic. The Pennsylvania railroad lines east of Pittsburg and Erie, 4,167 miles in extent, carried in 1897, 78,928,000 tons of freight, or over 2½ times as much as all the waterways of France. The average cost of moving this freight on the Pennsylvania was only 0.369 ct. per ton mile, and the average charge to the shipper only 0.536 ct. per ton-mile.

MONTREAL HARBOR PROJECTS are now deeply interesting business men of that city. The Dominion Government and the city authorities have both agreed upon extensive harbor improvements, and the Dominion Minister of Public Works has been authorized to loan the Montreal Harbor Commission $2,000,000, supplementing previous grants. As now planned, the work would cost $12,000,000, extending over a long term of years, and include guard piers, wharfage piers and frontage piers. The movement has received a new impetus by the reported application of Buffalo and Cleveland capitalists for dock privileges and permit to build great grain elevators. The syndicate asks for 1,200 ft. front at Windmill Point wharf, and 2,000 ft. front on the opposite side of the Windmill Point basin, under a 99-year lease. The Montreal Corn Exchange believes that the government should build these elevators and keep them under the control of the Harbor Commission, and is now interviewing the government on that head.

THE WIDENING OF THE DELAWARE RIVER water front in Philadelphia, commenced in September, 1897, is nearly completed. This improvement is about one mile in length, and extends from Vine to South St. It comprises a street 150 ft. wide, inside the main docks of the city, and the construction of new city piers at Arch and Chestnut Sts., both 500 ft. long by 80 ft. wide. Including the city piers, the work will cost $721,000, and over $700,000 more has already been paid out as compensation to property-owners. The work has been carried out under Mr. George S. Wester, Chief of the Bureau of Surveys, and his assistant, Mr. George E. Oatesman.

THE HAMBURG-AMERICAN STEAMSHIP "GRAF Waldersee" reached New York on April 15, on her maiden trip. This steamship is 565 ft. long, 62 ft. beam, 42 ft. deep, and 13,000 tons carrying capacity. She has two vertical quadruple expansion engines of 5,500 I.-HP. and a speed of 14¼ knots. She is a sister ship to the "Patricia," "Pennsylvania" and "Pretoria," of the same line, and was built by Blohm & Voss, of Hamburg, for the American trade. These vessels are all fitted with bilge-keels and are designed for comfort and carrying capacity, rather than for speed.

THE MORGAN LINE STEAMERS "El Norte" and "El Sud" were launched at Newport News on April 15. They are intended for traffic between New York and New Orleans and take the place of vessels of the same names sold to the government during the Spanish-American war. These ships are each 406 ft. long over all, 48 ft. beam, 33 ft. 9 ins. depth, 4,665 tons gross, and 2,905 tons net tonnage. They have triple-expansion engines, three double-ended boilers and are built of steel throughout. They cost $600,000 each, and two more will be built for the same line. They are fitted for cargo only and have no passenger accommodations.

AN ARMY CABLE SHIP is being fitted out at the Morse Iron Works, in Brooklyn, for use in laying cables in the Philippines. The ship is the U. S. transport "Hooker," formerly the "Panama," captured in the late war by the "Mangrove." Lieut.-Col. Maxwell, of the Signal Corps, will be in charge of the cable-laying, and the "Hooker" will have three cable-tanks and reels, and a full equipment of cable-cutting and repairing machinery and appliances.

A SPEED OF 33 KNOTS was made by the "Albatross," a new type of torpedo-boat-destroyer recently launched at the yard of Thornycroft & Co., at Chiswick, England. The destroyer is 227 ft. long, 21 ft. beam and 8½ ft. draft.

THE TUGRIN FOG-DISPELLER is described in the "Monthly Weather Review" as a pipe 8 ft. long and 3 ins. inside diameter, with a wide flare at the mouth, and is intended to be located on the ship near the navigating officer. A blower is arranged in the ship to send into this pipe, through a small tube, a powerful stream of warm air; this air is forced forward and blows a hole right through the fog. The fog is "rolled back in every direction," the moisture seems to condense and fall in raindrops, and it is claimed that the navigating officer is thus enabled to see several hundred feet through the densest fog.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the Southern Indiana Ry., near Bedford, Ind., on April 18, in which a train ran off a high trestle. Two men were instantly killed, another fatally injured and several badly hurt.

A CURIOUS RAILWAY ACCIDENT occurred on the Great Northern R. R., near Madison, Wash., on April 14, which resulted in the death of one man and the serious injury of three others. The accident was due to an avalanche striking a rotary snow plow, which, with a crew of 12 men, was at work clearing the track between Seattle and Madison. The plow was swept down the canyon fully 1,000 ft., and buried under snow so that the men had to be dug out.

THE FAILURE OF THE FALSEWORKS of the shore span of the Willis Ave. bridge over the Harlem River in New York city, April 11, resulted in the death of 6 persons and the injury of 21 others. Recent reports contradict the explanation of the accident given in Engineering News for April 13, and it now appears that one of the main bents of the superstructure failed and allowed the crane to fall, carrying down the entire structure. Just what caused the bent to fail is not known, but it is variously attributed to inherent weakness, insufficient depth of piling and unusual load due to a timber which the crane was hoisting catching in the bracing of the falsework.

DEFECTIVE SEWER WORK in Chicago is developing on the new intercepting sewers, thus lending strength to the allegation of the newspapers and some of the aldermen that a large amount of work upon these sewers is defective and not in accordance with the specifications. The Deputy Commissioner of Public Works, Mr. Toolen, recently examined the 45th St. sewer and found a bad sag in the arch between 20th and 21st Sts., together with other defects, including badly made cement in the brick work. It is also claimed that a report was made by an inspector last August, noting sags 75 to 200 ft. in length, and a crack 2 ins. wide and 75 ft. long at 20th St., in spite of which the assignee for the contractors (Campbell & Dennis), who had failed, had been allowed to draw the $8,000 held by the city as a guarantee that any defects would be remedied. The charges against the large sewers are mainly to the effect that one ring of brick has been omitted, and that the bricklaying and backfilling have been improperly done. Mr. Spangler, Assistant City Engineer, has made a report to the Commissioner of Public Works, stating that in the big Lawrence Ave. sewer only two rings of brick have been used for a distance of 66 ft. at Lakeside Ave. and Sheridan Road, although the specifications called for three rings. The contractors, Coogan & Pound, will have to remedy this defect. The responsibility for such defective work is usually laid upon incompetent and dishonest inspectors employed by the city and the contractors.

THE OFFER TO BUILD the New York Rapid Transit Ry., which was made by the Metropolitan Street Ry. Co., some weeks ago, was formally withdrawn on April 17, the company stating that because of the popular opposition which has been manifested to the company's demand for a perpetual franchise, it did not care to proceed with its application. Meanwhile there is some evidence that the present city officials have received some enlightenment respecting the extent to which popular sentiment favors the construction of the road by the city, and that it may yet be found possible to construct the road as a city enterprise.

THE POPULATION OF GREATER NEW YORK, on July 1, 1898, was 3,438,000, according to the New York Board of Health estimate. This population was divided as follows, by boroughs: Manhattan, 1,911,000; Brooklyn, 1,197,000; Bronx, 137,000; Queens, 128,000; Richmond, 65,000. This population is increasing at the rate of about 100,000 per year; the birth-rate being 23 per 1,000, and the death-rate 18 per 1,000. The rest of the increase comes from immigration from abroad and the movement towards New York from the surrounding states.

THE LAKE ST. ELEVATED RAILWAY, of Chicago, now has a surface line extension from 52d St. to Wisconsin Ave., 2½ miles, thus giving a new line for the suburb of Austin. An incline connects the end of the elevated railway at 52d St. with the new line, and as the latter is operated on the trolley-wire system, the motor cars will be equipped with trolley poles.

THE PENNSYLVANIA RAILROAD CO. was chartered on April 13, 1846, and the extent of the development of this road is shown in the following statement: In the first year of its existence it operated 224 miles of road and passed over this 70,000 tons of freight and 500,000 passengers. In 1898, the company operated nearly 10,000 miles of line and carried 173,791,329 tons of freight and more than 71,000,000 passengers. The net revenue for last year was almost $40,000,000.

GRAIN TRANSPORTATION RATES, between Chicago and New York and Boston, have been reduced from 20 to 17 cts. per 100 lbs., by an agreement among the trunk line managers. The boards of trade of Chicago and Peoria lately complained to the Interstate Commission that these localities were being discriminated against by the lower rates fixed by railways for the transportation of corn from Mississippi River points to the seaboard. The commission decreed that it was not equitable for railway lines to create artificial differences in market conditions by arbitrary differential rates, and permitted the reduction noted, but "Bradstreet's" hints that the more plausible reason for the change of rates is the increasing competition of Southern and Gulf ports for export business.

THE GRAND ISLAND BRIDGE, over the American arm of the Niagara River, is to be built by the Osborn Co., of Cleveland, O., and engineers are now at work on the site of the bridge, says the "Buffalo Courier." The project includes the use of 544 acres of ground on the island for the Pan-American Exposition and is intended to meet the previous objection "that adequate transportation facilities were not available," so far as Grand Island was concerned. The engineer for the bridge is Mr. Frank C. Osborn, M. Am. Soc. C. E., and the general plan includes two steam railway tracks, two trolley lines, two driveways and footways and two cycle paths. The men interested include Chas. D. Marshall, George H. Van Vleck, L. D. Rumsey, C. N. Boughton, J. N. Adams and Mr. Wheeler, President of the Western Savings Bank. It is believed that the bridge can be completed in less than eight months. Mr. W. A. Calhoun is the Resident Manager, at Buffalo, for the Osborn Co.

THE EXPORT OF AMERICAN IRON AND STEEL, says the U. S. Bureau of Statistics, is one of the most remarkable features in the late growth in the export in American manufactures. In the eight months of the fiscal year 1899, the export of iron and steel shows a gain in value of nearly $16,000,000 over the corresponding months of 1898, or a gain of nearly 70% over the previous year. For the eight months ending in February for the fiscal years given the imports and exports of manufactures of iron and steel stand as follows:

	Fiscal year.	Imports.	Exports.
Eight months of	1897.....	$10,517,588	$35,781,809
	1898.....	8,397,977	42,864,262
	1899.....	7,564,953	58,377,784

The increase is largely in wire-nails, steel plates, bars and rods; locomotives ($3,178,642 worth exported in the eight months of 1899); electrical and metal-working machinery, etc. Since 1880 the exports of this class of manufactures have increased in value, five times; and the imports have decreased to one-fifth.

THE BRIDGES ACROSS THE RHINE, NEAR BONN AND DUESSELDORF, GERMANY.

By Fritz Mueller von der Werra, Civil Engineer.*

(With two-page plate.)

The arch bridges over the Rhine, near Bonn and Duesseldorf, in Germany, the largest structures of their type outside of America, were opened to traffic during 1898, adding two imposing structures to the long list of great bridges which so distinctively mark the last decade of the century. The accompanying illustrations show all the more important features of these two bridges.

FIG. 1.—GENERAL ELEVATION OF BRIDGE ACROSS THE RHINE, NEAR BONN, GERMANY.

The Bonn Bridge.—For a stretch of more than 60 miles along the Rhine, in the neighborhood of the city of Bonn, no permanent connection between the shores has been available, and whenever the water condition, fog or ice-floes prevented the use of ferries and steamers, a roundabout way of nearly 40 miles across the bridge at Cologne has been necessary in order to reach the opposite side of the river. In spite of great financial difficulties which opposed the project to build a bridge, these impediments to traffic at last led to the issue of a prize competition in which the most prominent German bridge firms took part. Altogether 16 different designs, aggregating over 400 sheets of drawings, were presented. Prof. Reinhold Krohn, Chief Engineer of the Gutehoffnungshuette, in connection with the contractor, Mr. R. Schneider, and Architect Mr. Bruno Moehring, took first prize, and the Gutehoffnungshuette was subsequently awarded the contract.

As the profile, Fig. 1, shows, the bridge consists of one span of 614 ft., two spans of 307 ft., located symmetrically to the main span, and one span of 106 ft., all dimensions c. to c. of end-posts The two-hinged arch was adopted for all spans, which were accordingly computed with much care, the influence lines for each member being calculated analytically and checked by graphical methods.

The theoretical length of the end posts of the main span is 34 ft. 6 ins., the intermediate posts tapering towards the crown to about 15 ft. 8 ins. The highest point of the arch towers about 136 ft. above the mean water level of the Rhine, and the rise of the lower chord of the arch is about 97 ft. The radii for the circularly-curved top and lower chords are 640 ft. and 530 ft., respectively. The arch is composed of 24 panels of 25 ft. 6 ins. each, and the floor beams are carried by suspenders connected to the panel points of the lower chord, or are, near the piers, directly attached to the arch. The two arch trusses are spaced 29 ft. 6 ins., c. to c., without batter, allowing 23 ft. 5 ins. for the roadway and 11 ft. 3 ins. for a foot-walk on each side. This foot-walk is carried by the cantilever end of the main floor beams, which consist of plate girders between the trusses, and of frame-work brackets outside. Five rows of stringers, about 5 ft. 10 ins. c. to c., connect to the floor beams. Intermediate floor beams, spaced about 5 ft. 1 in. apart, subdivide the space between the stringers, and zinc-coated buckle plates of 3-16-in. thickness, matching the oblong spaces, carry a concrete bed reaching 3 ins. above the edge of the buckle plate. The concrete is covered with a layer of mortar 1 in. thick, on which wood pavement, 4¾ ins. thick, set in one to one asphalt mortar, is laid. In order to obtain an approximately uniform thickness of the concrete at any point of the cross-section, the height of the main floor beams is varied according to the transverse gradient of the street, as will be seen from Fig. 2. The two outermost stringers are lattice girders, the bottom chords of which serve as top and bottom chords for the roadway lateral system, as will be described later on, Fig. 2. The panels of the foot-walk are subdivided similar to those of the roadway, and special rolled shapes, 13½ ins. c. to c., are placed parallel to the axis of the bridge. The space between these shapes is closed with concrete, which is covered with a layer of asphalt 1 in. thick. The curb is made of sandstone over the whole length of the bridge. Gas and water mains are carried across through openings provided for in the web plates of the main floor beams.

The panel lengths and number of trusses are the same for the two 307-ft. spans, and the roadway construction, therefore, is alike, differing only for the small 106-ft. span, which contains four trusses. The lower chord of the 307-ft. openings is curved to radii of 516 ft. and 416 ft., and the theoretical height of the endposts is 25 ft. 2 ins., and 34 ft. 10 ins., respectively. The height of the side arches in the center is about 4 ft., and in the four center panels a solid web takes the place of the diagonals. The rise of the arch is about 31 ft., and the general dimensions may be seen from the profile, Fig. 1. On both sides of the steel structure a number of masonry arches permit the passage of high water. There are altogether two spans of about 46 ft., four spans of 42 ft. 6 ins., and a retaining wall for the approaches about 280 ft. long. A considerable part of the roadway has a grade of 1 in 30, Fig. 1. This may be thought to be very steep, for wood pavement especially. The fact, however, that several roads in the neighborhood, subject to the same traffic, and built with the same gradient as the bridge, had proved satisfactory, finally led to its adoption.

The wind pressure acting upon the main arch is transferred to the pedestals and piers by means of two main lateral systems. One main lateral system, which takes up the stresses resulting from the action of the wind upon the roadway construction and live load, is provided for in the plane of the roadway; a second main lateral system follows the lower chord of the main arch as far as the second panel point from each end, and mounts through the portal-posts to the upper chord, which it follows between the portals.

The first main lateral system is again subdivided into two systems, and consists of one cantilever lateral girder, supported at the foot of the portals and above the supports, cantilevering to panel points 3 and 21, respectively. This system is made up of the buckle plates in lieu of a web plate, and of U-shapes as top and bottom lateral chords, originally intended for cable boxes, Fig. 2. Another cantilever lateral truss is composed of the bottom chord of the outermost roadway stringer as top and bottom wind chords, of the floor beams as horizontal struts, and of diagonals. The top chords of the outside foot-walk stringer, and the outermost roadway stringer, are united by means of angles to triangular lateral systems along both sides of the roadway. At panel point 3 an expansion joint in the roadway allows freedom of motion of the arch under changes of temperature, and prohibits any thrust of the arch from being taken up by the roadway.

The second main lateral system transfers to the supports all stresses resulting from wind pressure upon the arch, including the wind reactions of the cantilever lateral system in panel points 2 and 22. In this case the chords of the arch act as lateral chords, and the diagonals consist of four angles, latticed on four sides, drawn together towards the end, and each end attached to a single connecting plate. The struts likewise are composed of four angles and lattice work. A sway bracing at every vertical post between the portals, consisting of struts and cross diagonals, adds to the rigidity of the structure.

FIG. 11.—ORNAMENTAL CAPITALS FOR TOLL HOUSE OF BONN BRIDGE.

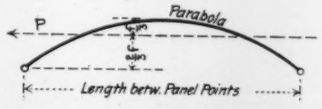

Fig. 1a.

The arrangement of the lateral and sway bracing of the side arches was designed on the same principle as that of the main span, being somewhat modified to meet the different conditions.

All members, including those theoretically in tension only, are made of stiff sections, which insure a relative resistance against buckling. Flat bars were permitted for lattice work, for all latticed members of importance, however, lattice angles were used instead. No metal of less thickness than 5-16-in. was allowed, the zinc-coated buckle plates excepted. To improve the appearance of the structure, the chords of the arches had to be bent to a continuous curve. Secondary stresses resulting therefrom, which in some cases exceed 20% of the primary stresses, were provided for by additional sectional area, and closely figured as follows:

Let S denote the permissible unit strain.
P denote the maximum axial stress of the member.
A denote the area of the section.
M denote the maximum bending moment.
R denote the moment of resistance.
f denote the height of the parabola.
k denote $\frac{R}{A}$,

and, if a parabola is substituted for the flat circle,

*22 William St., New York city.

to which each chord member is bent, the maximum lever will be ⅔ f (see Fig. 1a). Then,

$$S = \frac{P}{A} + \frac{M}{R} = \frac{P}{A} + \frac{P \frac{2}{3} f}{R} = \frac{P}{A} + \frac{P \frac{2}{3} f}{k A}$$
$$= \frac{P}{A}\left(1 + \frac{2 f}{3 k}\right).$$

and the required area will be found by trying different sections.

All details not easily accessible to inspection or to the paint brush were carefully avoided. Inasmuch as open-hearth steel was specified, hot

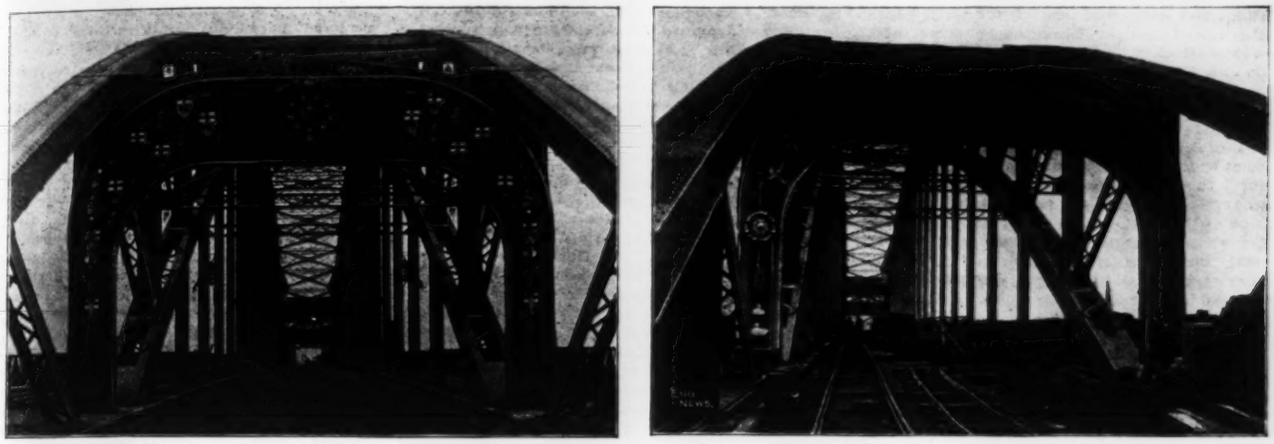

FIG. 12.—ORNAMENTATION OF PORTAL BRACINGS OF BONN BRIDGE.

crimping without subsequent annealing was undesirable. In all cases, therefore, where ordinarily crimping would have been necessary, wedge-shaped fillers were used, and the structural shapes were slightly bent cold. Great stress was laid upon the accurate intersection of the gravity lines of the different members meeting in one joint. As the drawings show, all parts of a chord section are spliced in the same point, thus reducing field reaming and riveting to a minimum. No holes,

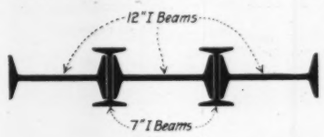

Fig. 2a.

not even in fillers, were punched, drilling having been used exclusively. The section of the top and bottom chord are the usual built-up box section, containing plates and angles distributed symmetrically to the center line, stayed by substantial diaphragms. The upper chord has top-cover plates; the bottom of the section is reinforced by flat bars riveted to the angles, thus leaving the section accessible from below. The lower chord is open at the top and bottom, with the exception of the two end panels, where bottom cover-plates are used, due provision being made for the efflux of water in this case. Rigid lattice work and heavy tie-plates insure the different parts of the section acting as a solid body. The diagonals consist of two or four plates and four angles united by lattice work. The posts are built up of angles and plates to Z-bar column sections. The connecting plates are cut to neat curves in order to aid the general appearance of the bridge. The pedestals, shown in Fig. 5, consist of a cast-iron footing, stayed by heavy ribs, altogether weighing about eleven tons, resting on large granite stones. The upper part consists of two cast-steel saddles receiving the steel trunnion about 10 ins. in diameter and 3 ft. long, which represents the "hinge" of the arch. An arrangement of steel wedges permitted a slight motion of the saddle pieces in all directions, and facilitated the adjustment during erection. A sheet of lead, about 5-32-in. thick, on the granite stones, made even by a layer of cement mortar, procures a uniform bearing of the pedestals, while the maximum unit strain on the granite exceeds in no case 55 tons per square foot. Fig. 2 shows the cross section of the bridge near the pedestals. Fig. 3 shows the portal construction generally, and details of connections. The end floor beam, Fig. 4, is allowed free motion in the axis of the bridge, being guided by a neatly-faced cast-iron shoe. Fig. 6 shows the framing of the arch ribs.

The arches have been dimensioned for a live load of about 80 lbs. per sq. ft., and the roadway construction for heavy concentrated loads, as deemed necessary. The coefficient of impact for the arches was 1.2, for the roadway construction 1.3, the wood pavement being assumed to some extent to neutralize the jars. For wind pressure about 50 lbs. per sq. ft. were assumed when the bridge is unloaded, and 30 lbs. per sq. ft., acting on the area of the steel construction and on a live load about 8 ft. high, was adopted for the loaded structure. A change of temperature of 126° F. was provided for. Open-hearth basic steel, of soft character, with an ultimate tensile strength of from 52,500 to 62,500 lbs. per sq. in., and a specified elongation of 20% in 8 ins. longitudinally, and 17% transversely to the fibers, was used for the bridge. The test pulls establish the following actual average values: Ultimate tensile strength longitudinally, 56,800 lbs. per sq. in., and 26.64% elongation, transversely, 57,300 lbs. per sq. in., and 23.85%. The test pieces of cast steel were required to show a respective value of 85,000 lbs. per sq. in., and 10% elongation, rigid inspection and testing being maintained throughout the work. The permissible unit strain for all parts of the construction were computed according to the formula:

$$S = 13{,}500\left(1 + \frac{1}{2}\,\frac{P\ min.}{P\ max.}\right)\ \text{lbs. per sq. in.}$$

Where P min. and P max. denote minima and maxima, resulting from dead load, live load and impact. Strains resulting from simultaneous action of dead load, live load, impact, wind and temperature, were specified, however, at no time to exceed 20,000 lbs. per sq. in. For the lateral systems the permissible unit strain had to be within the following limits: Diagonals, 13,500 lbs. per sq. in.; chords of roadway lateral system, 10,000 lbs. per sq. in. These low strains had been specified in order to reduce the horizontal deflection and vibration of the bridge under heavy gales. The shearing strain for the rivet-iron was not to exceed four-fifths, and the pressure on the semi-intrados eight-fifths of the axial strains. A factor of safety of five against buckling, computed according to the formula of Euler, was insured in all cases.

The total weight of the riveted structure, as shown in Fig. 7, reaches 3,000 tons, to which add 150 tons for balusters, railings and ornamental metal parts, and 127 tons of cast iron, and 55 tons of cast steel. A total of 760,000 wrought-iron rivets, of which 350,000 were field rivets, had to be driven.

The borings of the river bed revealed a stratum of hard sand with pebbles, about 46 ft. thick, on a bed of white, sandy clay. For the piers, therefore, concrete foundations, surrounded by sheet-

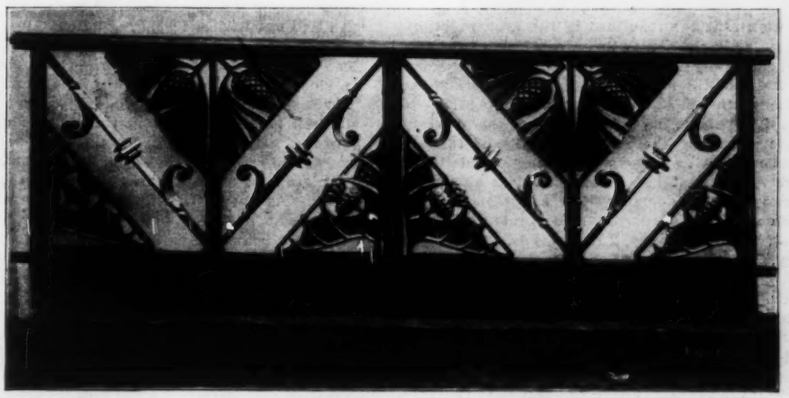

FIG. 13.—RAILING FOR BONN BRIDGE.

piling, was decided upon. The concrete base has a width of 45 ft. and a thickness of 16 ft. 6 ins. for the river piers, and 11 ft. 6 ins. and 13 ft. for the land piers, the top of the concrete being flush with the bottom of the river. In plan they are of oblong shape, with a triangular piece pointing up stream attached, the total length being about 69 ft. A cofferdam about 13 ft. 6 ins. wide, and reaching 6½ ft. above mean water, had to be constructed around each pier. The inside sheeting of the cofferdam, which also constituted the sheet piling of the foundation, was composed of 12-in.

and 7-in. I-beams, arranged as shown by Fig. 2a, the use of wood being precluded by the coarseness of the solidly packed river gravel, and the considerable bending moment caused by the great length of this sheeting. For the outside sheeting wood could be used. After the completion of the foundation the upper part of the I-beams was broken off, having at the proper height been previously weakened by holes, electrically drilled from inside the cofferdam. For that purpose two motors were installed on top the cofferdam, and connected to the drills by rope-transmission. Holes were then drilled through the webs of the 12-in. I-beams, and lengthwise through the whole depth of the web of the 7-in. I-beams. By means of a wire rope attached to a tug boat, and to the upper beam end, the I-beams were bent downward, and by means of a steam crane, pulled up again, and the performance repeated until the end broke off, this, as a rule, occurring after the beam end had been once bent up and down. The aggregate length of holes which could be thus drilled in one day was about 2 ft. only, which made the work so costly that, at the land piers, the removing of the upper portion of the I-beams was altogether abandoned.

The concrete was composed of one part Portland cement, three parts Rhine-sand, and five parts broken stone, to which a small portion of trass was added in order to produce quicker setting. The concrete was prepared on two floating mixers, whence it was conveyed by means of dump cars to two chutes, suspended to a movable working platform. The diameter of the chutes was about 2 ft., and the height of each dumped charge about 3 ft., the length of the chutes during the early part of the work being nearly 39 ft. A stone riprapping, flush with the river bed, about 30 ft. wide and 10 ft. thick in the average, is placed around each pier. The unit pressure on the foundation bed under no circumstances exceeds 5.1 tons per sq. ft. This is chiefly due to the favorable proportion of lengths of spans to the respective rises of the arches (1 in 7 and 1 in 11), which causes the resultant of the arch reactions to deviate only slightly from the center line of the piers. The rise of the arches was determined under the assumption that the resultant of the arch reactions intersected in the center line of the base of the pier, when the whole bridge was loaded to full capacity. The width of the masonry of the river-piers above the foundation is 35 ft., symmetrically tapering to 20 ft. 6 ins. above the pedestals. For the masonry of the piers and the retaining walls of the approaches, basalt stone was used, the outside being faced with basalt lava. All buildings above the roadway were made of yellow sandstone. Altogether about 9,150 cu. yds. of concrete, 22,500 cu. yds. of rubble masonry, 2,700 cu. yds. of arch masonry, 1,760 cu. yds. of basalt lava, and 1,640 cu. yds. of sandstone masonry were needed. About 130 cu. yds. of granite as bases for the arch pedestal must be added to the total. For the concrete about 7,500,000 lbs. of Portland cement, and 1/10 of this weight of trass were necessary.

The erection of the bridge covered a period of nearly three years. During the first year the work about the two river-piers was advanced to the height of the roadway, and about 105,000 cu. yds. of dredging was effected in order to provide a channel for the shipping traffic during the erection of the middle span. During the second year the middle arch was erected, the approach walls completed, and the land piers built up to the height of the roadway. During the third year the erection of the side arches took place, the masonry work and paving was completed, the balusters and the ornamental metal work were attached, and all the rest of the work successfully terminated.

The municipal regulations for the erection required that at all times a clear channel, unobstructed by any kind of falsework whatever, should be provided. This, of course, rendered it impossible to erect all the spans at the same time, especially since during the winter months the falsework had to be removed. It finally was decided to undertake the erection of the middle span first, chiefly to avoid the simultaneous start of work at all four main piers. This decision involved the disadvantage of having no permanent connection with the shore, and subjected the piers to the enormous thrust of the large span alone. However, in computing the river-piers, attention had been given to the fact that in case of war the blowing up of one of the side arches might be necessary, and the piers had been dimensioned accordingly. Accurate measurements which were taken by means of very sensitive instruments after the arch had been brought to bear on the pedestals revealed only a trifling deflection of the piers, which did not noticeably increase during the ensuing month.

The falsework for the erection of the bridge required about 185 tons of iron, and 850,000 ft. B. M of wood, although most of the timber for the temporary support of the main span (Fig. 8), was later used for the side arches. There was a passage for the river traffic provided for in the falsework of each arch, and a system of pyramidally driven piles, united by wire ropes, as shown in the illustration, proved a great protection to the structure. Three steam-pile drivers were put to work, and the uppermost points of the falsework soon reached the lofty height of 150 ft. above the water level. There was one bent to each panel point. Two rows of posts were carried up beyond the crown of the lower chord, and rigidly framed together by means of longitudinal sticks, on which the track for two portal travelers rested. The metal pieces, none of which exceeded the weight of 7.5 tons, reached the site by boat, and were transferred to trucks by means of two steam swinging cranes on one of the piers (Fig. 8). The trucks were hauled within the reach of the portal travelers, fitted out with two hoists of 6 tons capacity each, which undertook the final handling. For the erection of the roadway a substantial platform with railings had been constructed. A power station fitted out with a 12-HP. dynamo supplied the energy for electric light and machinery.

The erection of the middle span—the process for the side arches was practically the same—proceeded as follows: After the heavy cast pedestals had been placed in position, the chord members, simultaneously starting from the four pedestals towards the crown, were deposited in their respective places on screw-jacks resting on the scaffolding. As the work at the trusses progressed the roadway members were put together, the top of the floor beams being located by leveling. This operation at the same time determined the exact position of the lower chord, inasmuch as the suspenders connect with the floor beams. No splice-riveting was allowed to take place until the exact curve of the arch was attained by means of raising or lowering the screw-jacks; otherwise secondary stresses might have resulted, with detrimental effect, after the arch was lowered into a self-sustaining position. During the further advance of the work frequent corrections of the location of the lower chord had to be made, owing to the settling and compression of the wooden posts under the increasing weight, which finally reached 1,650 tons. The time required for the erection of the main span up to the closing of the arch was about twelve weeks. After all screw-jacks had simultaneously been released, and the arch been brought to bear on the piers, the deflection under the dead weight was found not to reach the amount previously computed and allowed for camber in the shops. The time consumed in erecting each of the side arches was 29 days only, which reflects credit upon Mr. K. Riensberg, who had charge of the erection of the entire metal work.

The bridge received one shop coat of linseed oil, and one of lead, after the erection another coat of lead and two coats of oil paint were applied, the last being of a greenish tint.

Before the bridge was finally open to traffic, a test, under live load, was made by crowding on the structure all the vehicles available in the city and neighborhood of Bonn. The result was a satisfactory one, inasmuch as the deflection did not reach the figures permissible and previously computed, chiefly owing to the rigidness of the riveted connections, whereas frictionless joints had been considered in calculating. The total number of 10-hour shifts worked was 212,800, one-half of this time being required for the steel construction (the rolling-mill work excepted), the erection of falsework and the painting, while the other half covers the masonry, foundation and all the other work. During the busy summer time about 150 workmen were employed on the site, the force being reduced about one-half in winter.

The cost of the bridge amounted to about $257,000 for the steel construction, and to about $380,000 for all the rest of the work, exclusive of dredging. The low price of the metal work was largely due to depression in the steel market, and the generally dull season in bridge work at the time the contract was awarded.

As a comparison to the practice in a first-class American bridge shop, it may be pertinent to dwell with a few words upon the shop methods in vogue during the construction of this bridge in the shops of the Gutehoffnungshuette. On the ordinary truly level working platform, consisting of parallel rails at suitable distances, one set of web plates, truly abutting and conforming to the exact shape of the arch, was laid out. On these web plates all the rivet holes were laid out by means of rule, square and divider, according to the shop drawings, which numbered about 150 sheets in this case. Then followed the drilling and finishing of the web, which in turn served as a template for all the other profiles connected to it. Different squads, each under a separate foreman, were assigned to the various portions into which the work was divided, and the same foreman attended to all work of his portion, from laying out to shop painting. After all pieces were properly assembled and fitted together, the shop riveting was effected by means of hydraulic riveters, and the painting concluded the shop work; thus one-half of the entire truss was completely put together in the shop prior to shipment.

FIG. 16.—GENERAL ELEVATION OF BRIDGE ACROSS THE RHINE, AT DUESSELDORF, GERMANY.

This bridge and German bridge work generally present two singular features upon which comment may properly be made. They are the frequent plate splices and the rare use of unequal-legged angles in place of equal-legged ones, where the former, from a structural point of view, would deserve preference. The reason in either case is economy. The splice is cheaper than the increase of the size of a plate beyond a certain though moderate limit, and the mill price of an unequal-legged angle exceeds that of an equal-legged one of the same weight.

The surroundings of the bridge caused its architectural appearance to receive especial consideration, and Prof. Krohn, Chief Engineer, who evolved the outlines of the structure, has been fortunate in the conception and lay-out of the proportions of the ponderous steel masses. Not less successful, however, was Architect B. Moehring, who designed the detail ornamentation, some of which are herewith illustrated. The stone portals are shown by Fig. 9; the toll-house and its details by Figs. 10 and 11. Elaborate relief forge work, touched up with colors, enlivens the bare space of the huge wind portals, as shown by Fig. 12. The balusters and railing, also ornamental forge work, are

shown by Fig. 13. Each panel point along the roadway is also emphasized by an immense forging in shape of a dragon's head.

The Duesseldorf Bridge.—This bridge, a general view of which is shown by Fig. 14, very closely resembles the Bonn structure, which, in fact, has served as a pattern for the outlines, and, with a few trifling modifications, for the arrangement of the structural details also.

The appearance of the bridge, from an architectural standpoint, does not present the favorable aspect of the Bonn structure, owing to the insignificant dimensions of the center pier in comparison with the gigantic twin arches; although the first impression of the elegant and airy steel bridge of 2,100 ft. length, over all, upon the spectator is a powerful one. The masonry part is designed in Renaissance style, as indicated by the stone portals shown in Fig. 15, which contain offices and dwellings for the bridge officials. Fig. 16 shows the profile of the bridge and general dimensions.

The two main arches have spans of 594 ft. 6 ins. between the vertical end posts, which have a height of 40 ft., the intermediate posts gradually tapering to 16 ft. 5 ins. in the crown. The rise of the lower chord is 90 ft., and each of the 25 panels into which either arch is divided has a width of 23 ft. 10 ins. The height of the crown above the mean water mark is 129 ft. There are three arches of 208 ft., 188 ft. and 166 ft. span, with ten, nine and eight panels of about 20 ft. 10 ins., respectively, on one side, and one arch of 198 ft. span, divided into ten panels, of about 19 ft. 10 ins. on the other. Two trusses, 31 ft. 9 ins. c. to c., support the roadway, the width of which is 26 ft. 10 ins., and 9 ft. 10 ins. are reserved for a foot-walk on each side, making a total clearance of 46 ft. 6 ins. between the balusters. A noteworthy difference between the Bonn and Duesseldorf bridges is the location of the wind portals, which were placed nearer the piers, thus considerably reducing the unsupported length of the top chord. All other differences are of so little account as not to warrant comment.

The material is basic Thomas steel, with a permissible unit strain very nearly the same as for the Bonn bridge. The total weight is about 4,970 tons, to which 160 tons for balusters and ornamental work must be added. For the main span and the three adjacent side arches wood pavement has been used, the remaining side-arch being paved with stone. The deepest gradient on the bridge is 1 in 40.

The center pier and one of the shore piers were founded pneumatically, while the remaining piers received a concrete foundation between wooden sheet piling. The contractors for this work were Phil. Holzmann & Co.

The erection of the steel superstructure, which was conducted on the same plan as at Bonn, required about six and eight weeks for the large openings, respectively, and averaged about five weeks for each side arch. The falsework for one of the main arches is shown by Fig. 17. The erection of the bridge consumed about two and a-half years only; the work at the foundations being started in June, 1896, and the whole completed early in November, 1898. The aggregate cost of the bridge was $905,000; $440,000 of this amount being the cost of the metal work. After subjecting the bridge to a similar loading test, as described for the Bonn arches, the bridge was open to traffic with an elaborate celebration.

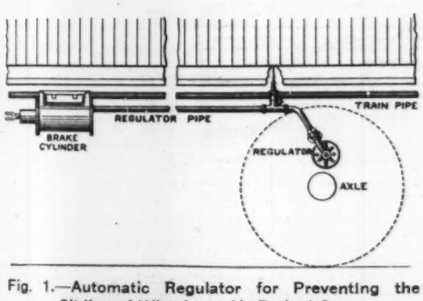

Fig. 1.—Automatic Regulator for Preventing the Sliding of Wheels on Air-Braked Cars.
Pacific Car Equipment Co., San Francisco, Makers.

Professor R. Krohn, Chief Engineer of the Gutehoffnungshuette, is also the designer and builder of this bridge. He was assisted by Mr. W. Kinkel, as principal assistant engineer for both the Bonn and Duesseldorf bridges, while the writer, as assistant engineer, computed and detailed one of the side arches.

A NEW DEVICE FOR PREVENTING THE SLIDING OF CAR WHEELS BY AIR BRAKES.

An air-brake regulator, designed for use in connection with the ordinary air-brake, to prevent the sliding and flattening of car wheels, has been recently experimented with on some of the railways on the Pacific Coast.

In general the device consists of a small friction wheel which is automatically placed in contact with the car axle whenever the brakes are applied.

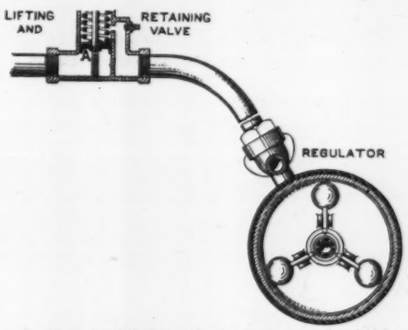

Fig. 2.—Detail of Automatic Arrangement for Lifting Regulator from Car-Axle.

This friction wheel drives a centrifugal governor, which controls air escape ports from a pipe connected to the brake cylinder. So long as the centrifugal governor revolves, these ports are closed; but the instant the wheel begins to slide, the governor stops, ports are opened, and the air pressure in the cylinder is reduced until the wheel again begins to turn. Fig. 1 shows the general arrangement of the apparatus, Fig. 2 a detail view of the lifting and retaining valve, and Fig. 3, a section of the centrifugal governing apparatus. The pipe which taps the air brake cylinder may be of very small size, ½-in. if desired. The lifting apparatus consists of a piston, A, Fig. 2, secured to a stem working through a stuffing box in the top of the T-piece; and this stem is secured to the car body at such a height that under normal conditions the centrifugal regulator hangs about 1 in. above the car axle. Above the piston, A, Fig. 2, is a spring which is normally compressed to such a point that the piston will not start to move upward until a pressure of about 20 lbs. per sq. in. is reached in the brake cylinder. When this point is reached, however, the piston moves upward, and allows the regulator to drop until it rests upon the car axle. At the same time it uncovers a port through which the air passes onward to the regulator, Fig. 3, where it passes through a hollow arm to the center of the axle on which the regulator turns. As seen in the drawing, this axle is made slightly tapering, and a sleeve which fits over this taper is moved by the governor balls to open or close the escape ports. It will be seen that these ports are all enclosed by the hollow revolving drum, so that they are protected from all dust and moisture. Small holes in the drum permit the escape of air when the ports open.

While at first sight it may appear necessary to attach this regulator to every axle of a car in order to have it prevent sliding wheels, it is claimed that in practice the rear wheels of the front truck always begin to slide first. Hence, if a regulator is applied to that axle on each truck toward the center of the car, the sliding of wheels will be prevented with the car moving in either direction.

The pressure to which the lifting piston is set and the speed at which the centrifugal governor will open the ports, can be adjusted to suit the requirements of any railway. Ordinarily the former is set to 20 lbs. pressure; and the centrifugal governor opens the ports when the speed falls to 2 to 3 miles per hour. This latter feature effects an automatic release of excessive pressure in the brake cylinder just before stopping, and considerably improves the smoothness of the stop.

A very interesting application of the apparatus is for use as a high-speed brake. As our readers will remember, much effort has been expended during the past ten years toward the production of a brake apparatus which would reduce the pressure in the brake-cylinder as the speed falls off and the coefficient of brake-shoe friction runs up. This little apparatus seems to meet the desired end. Any desired pressure can be reached in the brake cylinder and exerted upon the brake-shoes, and this regulator will not interfere in any way until a wheel slows down to begin to slide. It will then instantly reduce the pressure, but only to such a point that the wheel again rolls without sliding upon the rail. As a brake acts with the greatest possible efficiency when the brake-shoe pressure is just short of that which will slide the wheels, the device should be especially advantageous on high-speed passenger trains.

This device was patented on Dec. 7, 1897, and was put to actual test in October, 1898, on a Southern Pacific train running between Oakland and Sacramento, Cal., and has been in constant use there since that date. It has also been put on two of the four Berkeley local trains, where heavy grades are encountered, with very frequent stops. On March 20, 1899, Assistant Superintendent Thompson, of the first-named railway, reported that the device had proven its efficiency, and was in perfect condition; no wheel had flattened on a car with the regulator attached. The inventor claims that the tests on the Oakland-Sacramento line clearly demonstrate that, on a 5% grade leading to a coal-tipple, the efficiency of the air-brake in stopping a train was increased slightly over 30%. He further says that the effect of this regulator is to immediately start to rolling any pair of wheels that shows a tendency to stop while the train is in motion, and thus prevents the sliding and flattening of the wheels; it increases the efficiency of the brakes; does not release them when the train is stopped on a grade; and it enables the engineer to make quicker stops without danger to the wheels, as it decreases recoil or shock in stopping. The patent is controlled by the Pacific Car Equipment Co., of 206 Kearny St., San Francisco, Cal., which will send a description and instruction book explaining the installation and use of the apparatus on request.

THE INFLUENCE OF THE SIZE OF TEST PIECE ON THE COMPRESSIVE STRENGTH OF CAST IRON.

The report of the first set of tests made by the committee appointed by the American Foundrymen's Association to conduct an exhaustive series of experiments with cast iron to obtain data for the preparation of a standard set of test specifications, was given in Engineering News for March 9, 1899. This report was for "Cast A," soft Bessemer mixture.

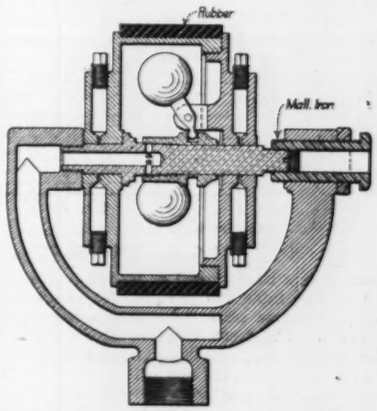

Fig. 3.—Sectional View of Regulator, Showing Centrifugal Governor.

Through the courtesy of the committee we are

enabled to present herewith the results of "Cast B," dynamo frame iron.

This set consisted of 198 bars, cast vertically and at the same time, in accordance with the specifications of the American Foundrymen's Association Committee on standardizing the testing of cast iron, and furnished 262 test pieces and 286 separate tests. The bars for this test were presented to the committee by the Westinghouse Elec. & Mfg. Co., Pittsburg, Pa., in the interest of the trade.

"Cast B" illustrates a class of castings which must machine readily, must be soft when cast in sections little over ½-in. thick, and yet sound when as thick as 14 ins.

In this material a good transverse strength and resilience is essential, tensile strength being less so.

The composition of this cast, of which about 40% was scrap, as taken from the 1 in. dry sand square bar, is as follows in per cent.: Total carbon, 3.82; graphite, 3.23; silicon, 1.95; manganese, 0.34; phosphorus, 0.405; sulphur, 0.042.

The cross section of the square and round bars is approximately equal for the relative sizes. The machined bars were turned or planed to the sizes given in the table for purposes of comparison. In the transverse tests the supports were all 12 ins. apart. The fresh fracture of each size of round and square, green sand and dry sand transverse bar was preserved and will be mounted in a case, which it is expected will be on exhibition at the coming convention of the American Foundrymen's Association in Pittsburg. From the physical structure of these bars it is seen that the larger sizes would be much better for standard tests than was the case with "Cast A," as shrinkage spots are not very much in evidence. However, there is a slight tendency to pipe, a circumstance fatal to the value of a test bar cast in any other position than the vertical. Only two bars proved unserviceable. The fluidity strips ran up nearly full.

Compression Test of ½-in Cubes of Dynamo Frame Iron. "Series B."

Test bar,* ins.	Crushing strength in lbs. From edge. Middle ½-in.	First ½-in.	Second ½-in.	Third ½-in.	Fourth ½-in.
½ × ½	38,380	.....	.....	.....	.....
1 × 1	23,000	27,440	.....	.....	.....
1½ × 1½	20,980	24,820	20,980	.....	.....
2 × 2	18,130	21,640	18,740	.....	.....
2½ × 2½	16,060	18,270	15,940	15,060	.....
3 × 3	13,790	17,000	14,410	13,900	.....
3½ × 3½	13,160	15,970	15,200	13,560	13,160
4 × 4	12,430	16,140	13,950	13,760	12,830

*Approximate cross section of test bar from which cube was cut.

Remarks.—The cubes were cut from the square bars cast in dry sand (vertically) and were compressed along the length of the original bar. Test pieces were cut along a line at right angles to the sides of the bar. The value of the middle cube is repeated where it rounds out the series.

THE CALCULATION OF I-BEAM GRILLAGE FOUNDATIONS.*

By J. B. Nau.†

The following easy and rapid method of calculating I-beam grillage foundations, such as are commonly used in tall building construction in Chicago, Ill., and other large cities, is submitted with the idea that it may be found useful by engineers having the design of such foundations in charge. This determination is based on the assumption that in such foundations the strength of the beams can be calculated by means of the strain to which the part of the beam in cantilever is submitted. A table of curves, Fig. 1, has been established giving the safe load per running foot of standard I-beams, from 5 ins. to 24 ins. height, when used in cantilever varying from 1 ft. to 8 ft.

This safe load per running foot is given by the expression,

$$W = \frac{S\,I}{6\,n} \times \frac{1}{l^2},$$

where,

W = load in pounds per running foot.

S = 16,000 lbs. stress per sq. in. in extreme fibers of beams.

M = distance from center of gravity of sections to top or bottom.

I = moment of inertia of section, neutral axis through center of gravity.

l = span in feet.

No greater span than 8 ft., even for the heavy beams, has been considered, as such spans are seldom if ever used in this kind of work. For the same reason no shorter span than 1 ft. cantilever has been considered for the lighter beams.

The use of the table will be best explained by an example of a grillage foundation supposed to be required to carry a superimposed load of 720 tons. We further suppose that the ground under the foundation can safely carry a load in the neighborhood of 3.5 tons per sq. ft. Making the base of the grillage foundation 18 ft. × 12 ft., Fig. 2, we can carry 18 × 12 × 3.5 = 756 tons. This leaves 756 − 720 = 36 tons for the weight proper of the grillage foundation. The base of the column shoe on top of the grillage foundation is supposed to be 4 ft. square. These data established, it will be easy to determine the size and number of the I-beams used in the three different layers of the foundation considered.

Fig. 2.—Typical I-Beam Grillage Foundation, Illustrating Use of Diagram.

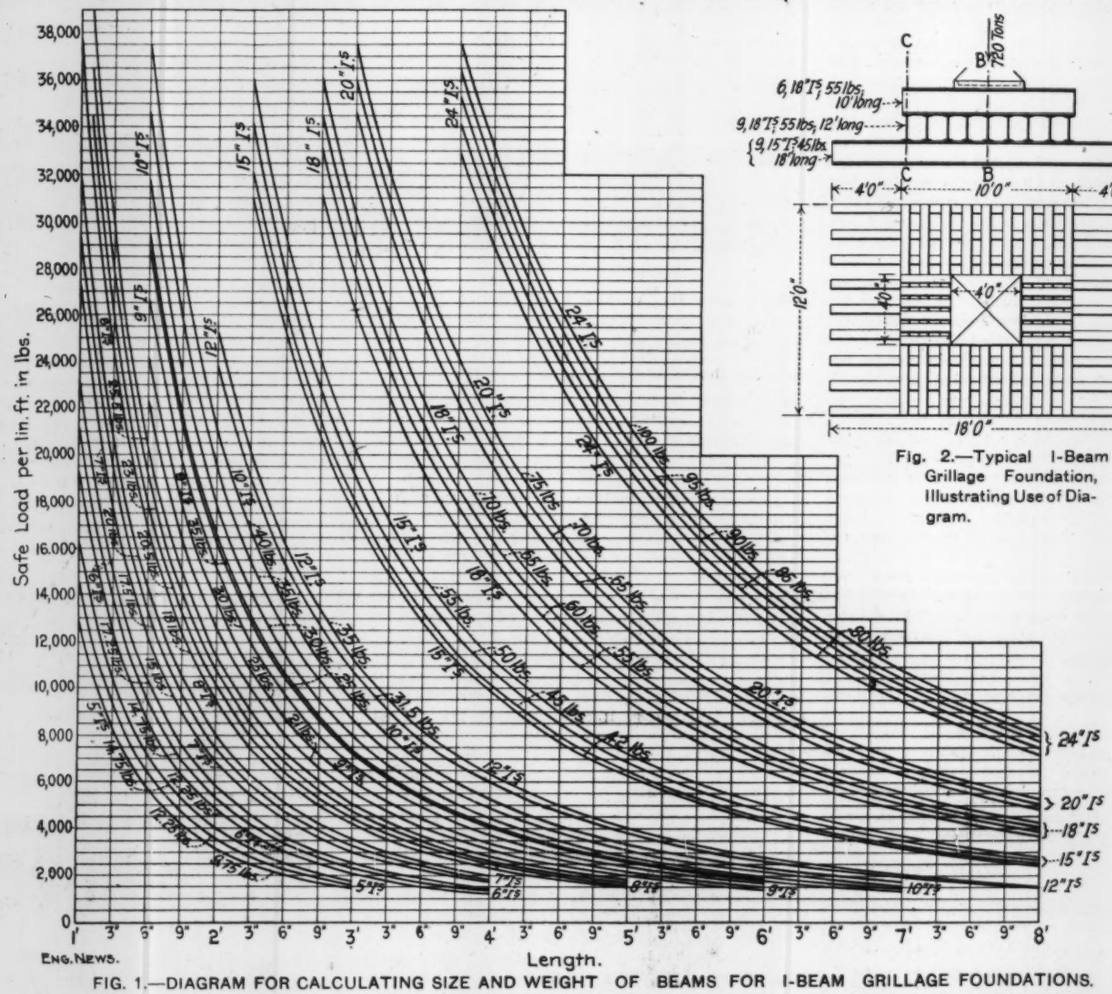

FIG. 1.—DIAGRAM FOR CALCULATING SIZE AND WEIGHT OF BEAMS FOR I-BEAM GRILLAGE FOUNDATIONS.

The upper layer is composed of six 18-in., 55-lbs. I-beams, placed 8.4 ins., c. to c. These beams with the concrete will weigh about 8 tons. The total load to be carried by the beams = 720 + 8 = 728 tons. From outside to outside of beams, the width is 48 ins., the width of the shoe above. Each strip 1 in. wide, parallel to the direction of the beams, will have to carry $\frac{728}{48} = 15.16$ tons. Each inside beam will carry 15.16 × 8.4 = 127.34 tons over a length of 10 ft., or 12.73 tons for each running foot.

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†134 West 83d St., New York.

The table will show that an 18 in., 55-lbs., I-beam will carry, when used with a cantilever of 3 ft., a load of 13.06 tons per running foot. The beams chosen are, therefore, strong enough to carry a load of 12.73 tons per running foot. Of course, by changing their number in the layer and, if necessary, their cantilevers, beams of a different size may be taken. In their choice one must be guided by the local conditions, as well as by the desire to reduce the weight of the beams to a minimum. The beams in the other layers will be determined in a similar way.

Basing the above method on the safe carrying capacity of the cantilever of each beam, we have followed the rule usually applied by engineers in this kind of work. We wish to state here, however, that the correctness of this assumption is disputed by some engineers, who claim that the most strained part of the grillage beams is not in the section B B, Fig. 2, where exists the maximum cantilever moment, but rather in the central section C C.

To demonstrate this, let A C = a be the left half of a grillage beam, with a cantilever of A B = c. The load transmitted to the beam is equally distributed over a length B C = b, while the reaction below is equally distributed over the length A C = a. Let p be the reaction per running foot; the whole reaction will be a p. Let p^1 be the pressure per running foot; the whole pressure will be $b\ p_1$ a p = $b\ p_1$, hence

$$p^1 = p\ \frac{a}{b} \qquad (1)$$

Taking moments around a section X X at a distance X from the central line, we shall have,

$$M_x = \frac{(a-x)^2}{2} \times p - \frac{(b-x)^2}{2} \times p_1$$

$$= \frac{x\ p}{2}\left\{a^2 - x^2 - \left[\frac{a}{b} - 1\right] - a\ b\right\}. \qquad (2)$$

M_x is the general equation of the bending moment.

We notice that the coefficient $\left(\frac{a}{b} - 1\right)$ of x^2 is always positive, b being always smaller than a. If we vary the value of x between o and b, the only limits, that interest us, we shall have the maximum for M_x, when x = o in central section C C.

$$M_{max} = \frac{x\ p}{2}\left\{a^2 - a\ b\right\} = \frac{p\ a^2}{2} - \frac{p_1\ b^2}{2}. \qquad (3)$$

From this formula the value of the greatest strain in the central section can be obtained. Formula (3) can be established directly.

Making x = b, we obtain the minimum moment, or the moment around section B B.

$$M_{min} = \frac{p}{2}\left[a - b\right]^2. \qquad (4)$$

This mimimum moment is really the maximum cantilever moment; the one that has been used in the establishing of the curves, and that is also generally used by engineers to determine the strength of grillage beams. It can be established directly. Yet grillage beams established with the use of the formula (4) or the maximum cantilever moment, are found to be strong enough, at least it has never come to the knowledge of the writer, that beams carefully calculated in this way, were found to be deficient.

When we established the above general formula (1) we have in fact considered the equally distributed reaction a p as being loosely applied over the whole length of the beams, allowing each part to act independently of any other part. This, however, is not the case in a grillage foundation. Here the reaction is given by the soil, or by a heavy bed of concrete under the beams, resting directly on the soil. The safe compression to which the engineer subjects the soil per square foot should be, and in well-established foundations is, small enough practically to prevent any uneven sinking. Furthermore, the grillage beams are not working independently, but are all thoroughly imbedded in a strong mass of concrete, which not only adds its strength to the strength of the grillage beams, but is such that the length B C of the beam can be considered as invariably fastened in it. Under such conditions, it is fair to determine the size of the beams with the use of the maximum cantilever moment with which the table of curves has been plotted.

In conclusion we wish to call the attention to the necessity of checking the strength of the beams in regard to shearing and bending of web as well, before definitely adopting any set of them. This part, of course, has nothing to do with the above calculation, yet in some cases it may happen, that beams strong enough to resist bending, would have to be rejected because they would be too weak to safely withstand shearing and buckling strains.

PROGRESS IN THE EQUIPMENT OF RAILWAY ROLLING STOCK WITH SAFETY APPLIANCES.

At the meeting of the American Railway Association, held at Detroit, Mich., on April 12, the committee on safety appliances presented a report which included the accompanying summary of the number of freight cars in service on the dates mentioned, the number equipped with automatic couplers and air brakes, and other data of interest. The table was prepared from replies to questions sent out in circular form by the committee:

It will be seen from these figures that 270,529 freight cars still remained to be equipped with automatic couplers on Jan. 1. Probably 50,000 or so of these are old cars, which will be either thrown out of use entirely or transferred to local traffic, or to use in work trains at the beginning of next year, when the Federal law goes into effect, requiring automatic couplers on all cars used in interstate commerce. There will be left, on this supposition, about 220,000 old cars to be equipped with automatic couplers during the present year, or about the same rate of progress as was maintained during 1898. There is no reason, therefore, why the railways should not be in a position to comply with the requirements of the Federal law by the beginning of 1900, when the extension of time allowed by the Interstate Commerce Commission will expire.

It should be noted that on each of the three dates shown in the table, all the new freight cars reported as under construction were to be equipped with both automatic couplers and air brakes, and all the new locomotives were to be equipped with power brakes.

The Equipment of Freight Cars and Locomotives with Automatic Couplers and Power Brakes.

	Jan. 1, 1897.	Jan. 1, 1898.	Jan. 1, 1899.
Number of roads reporting	167	196	182
Freight cars in service	1,054,815	1,110,045	1,168,810
Fitted with air brakes	385,682	460,005	617,234
With standard auto. couplers	517,617	674,675	898,281
Engines in service	31,590	32,771	32,882
Equipped with power brakes	27,458	29,827	31,034
New equipment, other than passenger, under contract or const'n: Freight cars	3,221	14,717	32,614
Locomotives	78	217	440

A FORM FOR PIPE-LAYING RECORDS.

Mr. Dow R. Gwinn, Superintendent of the waterworks of Quincy, Ill., has sent us a form for keeping records of pipe-laying which he has lately compiled.

The form is printed on both sides of heavy, tough paper, 10 × 14½ ins. in size, colored a light greyish green. It is arranged to fold twice, for filing, making the size 4 × 10 ins. The upper side of the folded paper is provided with blank spaces for describing the work in question, together with the date water was turned on, and the page of the book in which the record is entered. The other side of the folded paper is blank, but the balance of the sheet, on that side, is used for time rolls and a general summary of labor and material used on the job.

The reverse of the form provides for a full detailed record of one block of pipe-laying. The main features are: The street, and between what streets the pipe was laid; size of pipe used, weight per foot, manufacturer, cost per ton of both pipe and specials; date of beginning and finishing work, and of turning on water; location of pipe in street and depth of top below street surface; location and description of specials, hydrants and valves, including the year the hydrants were made and the date on which the city council ordered them set; a summary of length of pipe, hydrant branches and notes on the location of intersecting mains and of services; a general summary of the whole job; a diagram for sketching in the location of the new work and its relation to old; and, finally, spaces for the signatures of the superintendent and foreman.

Regarding the form, Mr. Gwinn writes as follows:

> I am confident that it would be very interesting to the water-works fraternity in general, as with this form a superintendent could specify the specials, besides the kind and size of pipe that would be used on any particular job, make a sketch thereof, and the foreman would have a minimum amount to write to make the record complete as far as he was concerned, while the averages and costs could be added after the report was returned to the office. A suggestion that led to the compiling of this form was received from a similar one used by the Denver Union Water Co., i. e., I got the general idea from their form and arranged the details in accordance with my own ideas.

We regret that it is impracticable to reproduce this form in our pages. A fair idea of its features may be obtained from the description we have given, and doubtless Mr. Gwinn will be glad to supply copies of it to those wishing fuller details.

A PATENT PLUMB-BOB, called the "Nacke," is made and sold by Ripka, Weil & Co., dealers in draftsmen's supplies in Philadelphia. The hardened steel point is removable, so that it can be taken out for sharpening, or be replaced by a new one; and when not in use it can be drawn up into the body of the plumb-bob and thus protected. These plumb-bobs weigh from 8 to 16 ozs., and cost from $2.50 to $3.50 each.

WEATHER TABLE FOR MARCH, 1899 (Furnished to Engineering News by the Department of Agriculture.)

	Stations.	Temperature. (Degrees Fahrenheit.) Average.	Max.	Min.	Range.	Wind. Velocity in miles per hour. Average	Max.	Direction at time of max. velocity.	Precipitation—Rain or melted snow. (Inches.) Total.	Heaviest in 24 hours.	No. of rainy days.
Northern Cities.	Northfield, Vt.	23.1	46	—4	50	10 2	42	SW	4.03	0.76	20
	Portland, Me.	29.3	48	10	38	8.7	37	NE	6.49	1.12	19
	New York City	38.4	64	20	44	18 9	80	N	6.78	1.27	18
	Pittsburg, Pa.	40.2	71	13	58	6 9	33	NW	3.37	0.80	16
	Chicago, Ill.	29.8	64	3	61	18.4	88	SW	2 11	0.67	10
	Omaha, Neb.	26.8	68	—2	70	10 1	30	NW	0.64	0.40	10
	St. Paul, Minn.	17.4	35	—11	46	8.7	28	NW	2.87	1 87	9
	Duluth, Minn.	15.2	34	—10	44	11.5	36	NE	0 82	0.32	7
	Bismarck, N. Dak.	7.5	50	—19	69	10.4	34	NW	0.88	0.33	8
	Average.	25.3	53	00	53	11.5	42	—	3.11	0.80	13
Southern Cities.	Washington, D. C.	42.2	72	19	53	9.8	46	W	4.94	1.33	12
	Louisville, Ky.	43.2	73	3	70	11.5	40	S	7 02	1 67	19
	St. Louis, Mo.	39.6	69	3	66	12.7	60	SW	3.96	1.95	14
	Savannah, Ga	61 0	85	24	61	10.5	40	NW	2.53	1.02	9
	Kansas City, Mo.	35 0	69	6	63	10.5	33	SW	2.95	1 59	12
	Jacksonville, Fla.	64.6	86	26	60	8.3	38	SW	1 35	0.62	5
	Chattanooga, Tenn.	50 4	79	2	77	9.2	50	SW	14 05	5.14	18
	New Orleans, La.	64 4	84	38	46	11.7	37	NW	2 71	1.85	10
	Memphis, Tenn.	51.0	80	15	65	14.3	46	SW	3 03	0 85	15
	Palestine, Tex.	60 4	88	26	62	10 9	29	SW	1.43	0.64	7
	Average.	51.2	78	16	62	10.8	42	—	4.40	1.67	12
Western Cities.	Helena, Mont.	22 6	55	—7	62	6.5	44	SW	1.27	0.33	12
	Port Crescent, Wash.	39.3	52	26	26	4.3	20	W	2.99	0.55	15
	San Francisco, Cal.	52.2	74	42	32	9.8	36	W	7.61	2 15	18
	Salt Lake City, Utah.	40 6	67	20	47	6.8	32	S	2.94	0.51	16
	Santa Fe, N. Mex.	40.4	68	18	50	8.0	32	NW	0 35	0.35	2
	Denver, Colo.	33.2	69	—5	74	9.0	50	W	1.10	0.63	10
	Yuma, Ariz.	—	—	—	—	—	—	—	—	—	—
	Average.	38.0	64	16	48	7.4	36	—	2.71	0.75	12

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ADVERTISING RATES: 20 cents per line. Want notices, special rates, see page XIX. Rates for standing advertisements sent on request. Changes in standing advertisements must be received by Monday morning; new advertisements, Tuesday morning; transient advertisements by Wednesday morning.

The example set by the Spring Brook Water Supply Co., of Wilkes-Barre, in establishing a complete chemical and bacteriological laboratory, is one that might be followed to advantage elsewhere. This is the first systematic work of the kind undertaken by a private water company, so far as we know, and the municipal laboratories are so few that this private one may well be held up as a good example to cities as well as companies. We stated in our issue of March 16 that Prof. W. H. Dean had been placed in charge of the laboratory, as Chemist and Biologist. In response to a request for information, Professor Dean has sent us an outline of the conditions leading to the establishment of the laboratory, and the work which he proposes to do. As the letter is brief, instructive, and enforces the points we wish to make, we quote it practically in full, as follows:

> The Spring Brook Water Supply Co. controls a number of watersheds, comprising about 100 sq. miles of territory, most of which is in an uninhabited mountainous region. These watersheds are drained by numerous streams fed largely by mountain springs, and on which are constructed several large impounding reservoirs. The company also has a pumping station at West Pittston on the Susquehanna River, with a capacity of 12,000,000 gallons daily, which, however, is used only in case of emergency. These various sources supply a population of over 225,000 people, besides numerous collieries and manufacturing establishments. These watersheds, by virtue of their location and their great freedom from human habitation, are well calculated to yield an abundant supply of pure water, and are kept under constant surveillance. But the company, wishing to leave nothing undone which might at all times insure to their consumers a supply of pure and wholesome water, has equipped this laboratory for the chemical, microscopic and bacteriological examination of water. My duty, as having charge of this work, is to periodically inspect the different watersheds, and to make frequent examinations of the water from the different sources of supply, some fourteen in number, that a thorough knowledge may be obtained of the character of each of these waters, the effect upon them of rainfall, change of season, storage, etc., and also as a check upon the filters used. The company operates three filters, two mechanical filters of the Morison-Jewell type, and a filter gallery under the river bed at their West Pittston pumping station.

We believe this will prove to be a wise expenditure of money. Most water-works are being operated quite blindly, as regards the quality of supply. Where no attempt at purification is being made frequent analyses are needed, on many works, to determine whether the supply is not already dangerous, or becoming so, or might not be greatly improved in quality, perhaps at slight expense. In the case of waters subjected to some form of treatment for improvement in character, intelligent and economical operation of the works to that end demands constant chemical or bacteriological examination, or both. A few cents of needless expense to each million gallons treated will often more than make up for the cost of such supervision. If human lives are involved, the need of such services becomes imperative, and the saving to be effected is measureless.

We are glad to see that the microscopic examination of water is to be a feature of the new laboratory. This is a line of work which has been carried on systematically only in the water supply department of three or four cities, but which is full of promise. Mr. Whipple, in his recently published book,* is doubtless technically correct in saying that the microscope is chiefly of value as an aid in detecting matter in water which is esthetically objectionable, rather than positively dangerous, but no one will dispute the assertion that tastes and odors are far more generally recognized and protested against than most infractions of esthetic principles.

A conspicuous example of bad taste in the use of ornament in bridge architecture is exhibited by the illustrations of the great arch bridge across the Rhine, at Bonn, Germany, which are presented elsewhere in this issue. Indeed, it would, probably, require considerable search to find a more striking instance of a bridge made ridiculous by its ornamentation than this notable German work. This defect is all the more noticeable because European engineers usually pay far more attention to artistic bridge design, and secure much better æsthetic results in their bridges than American engineers. It is hardly necessary to point out in detail the incongruity of the designs which we illustrate for the use to which they have been put, in connection with the massive metal work of a great bridge. They have not only the inappropriateness which excessive ornamentation always has in such a position, but they are further objectionable because of the triviality, and in some instances the absolute clownishness, of the designs themselves. Certainly such grotesqueries in stone and metal have no place in a bridge structure whatever place we may be inclined to allow to ornament in the abstract. As we have pointed out before, however, there is a strong objection to the use of small and detailed ornamentation in bridge construction entirely aside from the tastefulness of the designs themselves. Bridges as a rule are seen at a distance, and if of any magnitude can only be seen in part when one is near. They therefore impress the spectator favorably or unfavorably by their beauty of line and mass, and no minor ornamentation can alter this to its material damage or improvement. This fact is well shown by the Bonn bridge itself, which, viewed from a distance, affords a pleasing impression of boldness and grace despite its ill-chosen ornamentation. In other words, it is the agreeable relation between the units of the bridge from the proportions of piers and spans down to the subordinate relations of railing and cornice, or capital, shaft and base, which make a bridge sightly when viewed as a whole. Ornament is allowable only in so far as it serves to accentuate these relations to a needful extent. This same care to secure refinement in proportion and line, and to obtain an agreeable adjustment of detail, must also be depended upon to temper the harsh and rigid lines and surfaces of the metal work when viewed close at hand. Without this any form of ornamentation, however delightful in itself, can serve no æsthetic purpose.

It is true that upon many European bridges profuse ornamentation has been used upon accessory structures in connection with bridges with great success. Some notable examples were given in the views of famous European bridges in our issue of June 17, 1897. But in all cases the ornamentation in these successful designs has been in accord with the canons of good taste. Statues, carvings, bas-reliefs and other ornamentation upon portals, railings and piers have been themselves dignified and beautiful. Caricature has its place in the world; but that place is by no means in the architectural ornament of a dignified structure, no matter with what artistic skill it may be executed.

*"The Microscopy of Drinking Water." By Geo. C. Whipple.

THE ECONOMICS OF RAILWAY LOCATION

On the theory and practice of railway location much has been written, but in most cases the subject has been treated as a general proposition and analyzed in a more or less mathematical style. A broad discussion of the underlying economic principles which should govern location because of its important relation to construction and operation, has been seldom undertaken. For this reason we have been particularly interested in the new book of rules and instructions for the engineering and construction departments of the Northern Pacific Ry., a copy of which we have recently received from Mr. E. H. McHenry, M. Am. Soc. C. E., Chief Engineer of that company, under whose direction it has been prepared. It covers location, construction and maintenance, and some portions are reprinted elsewhere in this issue by special permission.

Perhaps the most important feature of this book, and certainly one of the most novel, is that which relates to the economics of location, or the relations between location and operation. It is, we believe, the first attempt to publish condensed instructions on this important subject, and to reduce the principles involved to practical rules for the guidance of engineers in the field. These rules are given, practically in full, in another column, and it will be seen that the subject is treated in a thoroughly scientific manner, and with a clear perception of its bearing upon the problem of economical operation.

The rules and instructions will be of exceptional interest to our readers, and might form the subject of more than one editorial, but we will here refer only to the subject of grades. We find no less than four classes of grades treated of: (1) ruling grades, which limit the maximum weight of trains; (2) maximum grades, which may be operated by heavier engines or assistant engines; (3) virtual grades, whose rate represents the real resistance (in excess of rolling friction) taxing the engine cylinder; (4) momentum or velocity grades, introduced to avoid increasing ruling grades by giving a run at the hill. The discussion of the relations of these grades to operating conditions and train service is of special interest at the present time, when so much attention is being given to the reduction of operating expenses by increasing the train loads until they approximate pretty closely to the maximum power of the engines.

Some of the matter contained within the instructions has been drawn from the late Mr. A. M. Wellington's well-known book on "The Economic Theory of Railway Location," supplemented by original matter derived from experience on the Northern Pacific Ry. The theory of virtual grades given in that work has been considerably extended and reduced to practical rules. Mr. McHenry states, in sending us these instructions, that in the discussion of this problem Mr. Wellington erroneously assumed equal tractive power of the engine at all speeds. The engine power may be regarded as a constant, being the product of the speed and tractive factors. These factors vary reciprocally, as shown by a diagram of engine horse powers, which is reproduced in another column, being taken from the instruction book above mentioned.

As an instance of the practical influence of location upon construction and operating expenses, it may be noted that within recent years the Northern Pacific Ry. has expended considerably more than $1,000,000 in grade reductions. The practical application of the theory of "virtual grades" has saved the railway company not less than $300,000 in the first cost of the improvements. In addition to this, it has made it practicable to reduce the ruling rate of grades 0.4 per cent., at far less cost than was originally estimated for reductions to 0.5 per cent. only.

Nearly all our trunk lines have carried out extensive works of a similar kind, and based more or less upon the economic principles and traffic conditions herein referred to, but very little has been

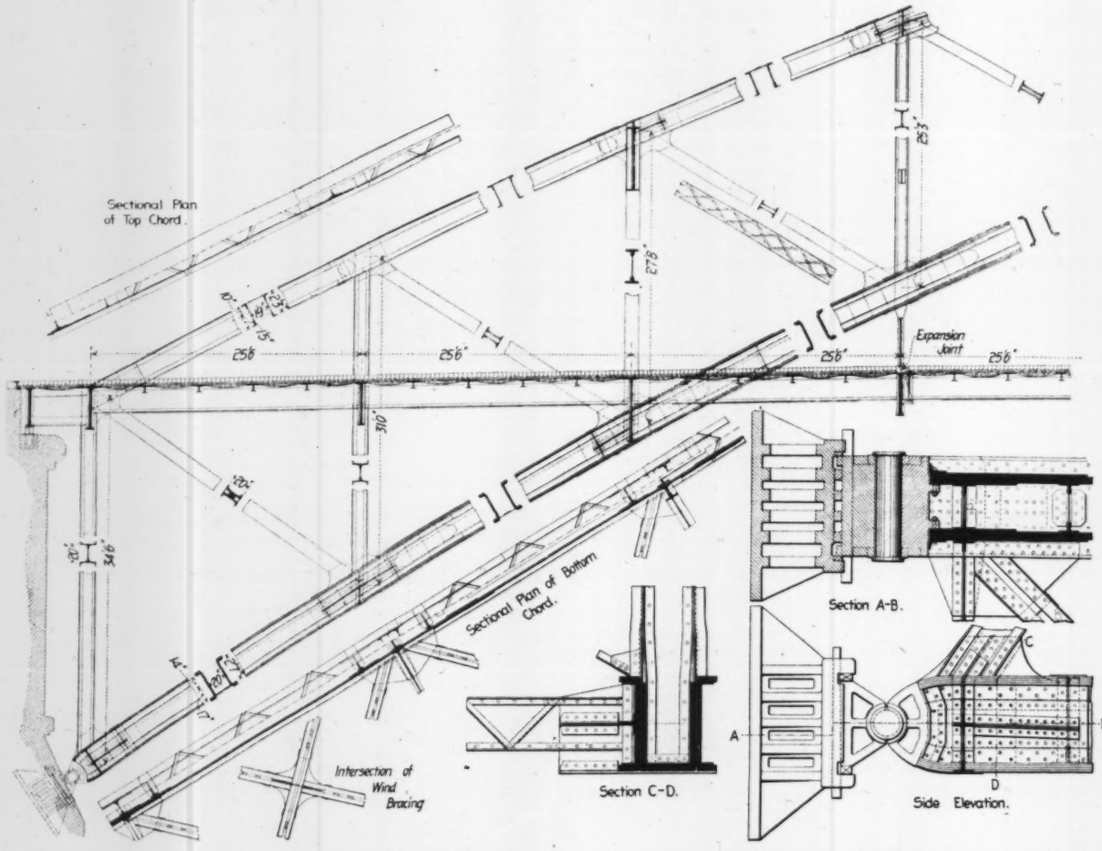


FIG. 6.—ARCH RIB FRAMING, BONN BRIDGE.

FIG. 5.—END BEARINGS FOR MAIN ARCH, BONN BRIDGE.

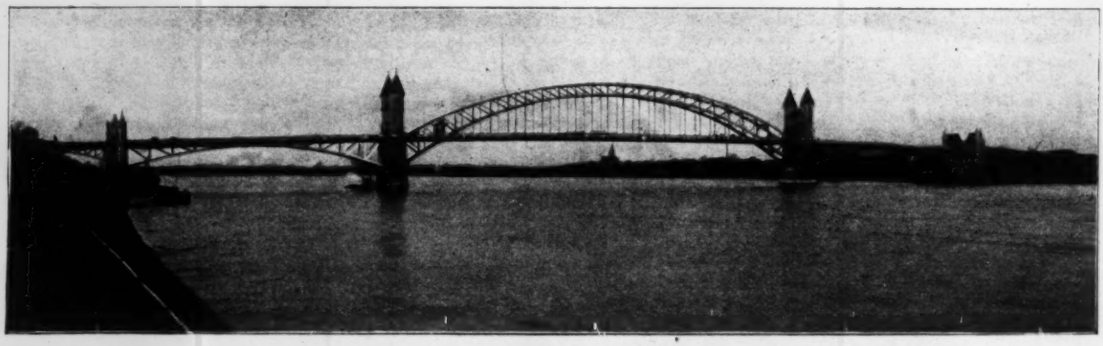


FIG. 7.—GENERAL VIEW OF STEEL ARCH BRIDGE, CROSSING THE RHINE, NEAR BONN.

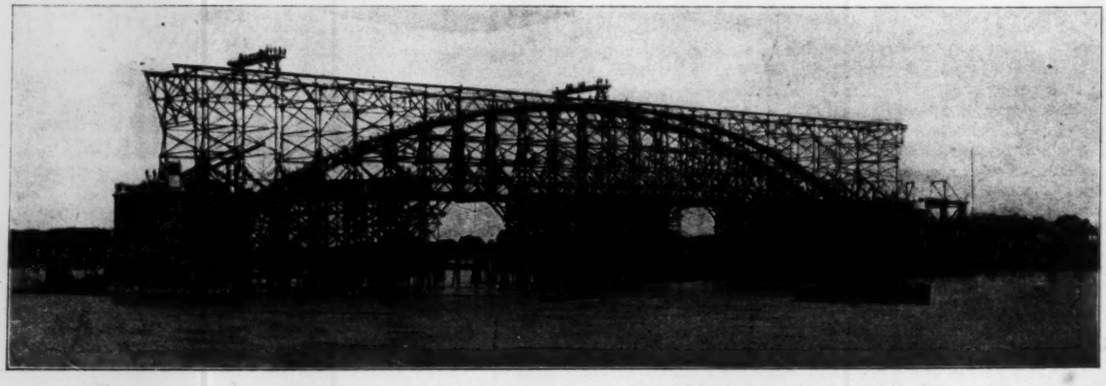
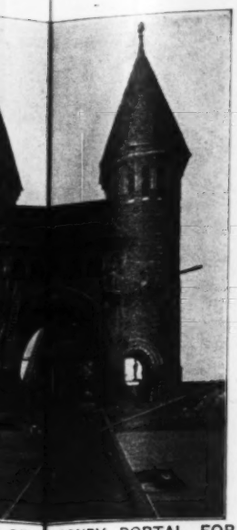


FIG. 8.—VIEW OF FALSEWORKS FOR 614-FT. CENTER ARCH, BONN BRIDGE.

FIG. 9.—VIEW OF MASON BONN BRI

FIG. 15.—MASONRY PORTAL F BRIDGE.

BRIDGES
OVER THE RHINE
NEAR BONN
AND DUESSELDORF,
GERMANY.



OF MASONRY PORTAL FOR BONN BRIDGE.

PORTAL FOR DUESSELDORF BRIDGE.

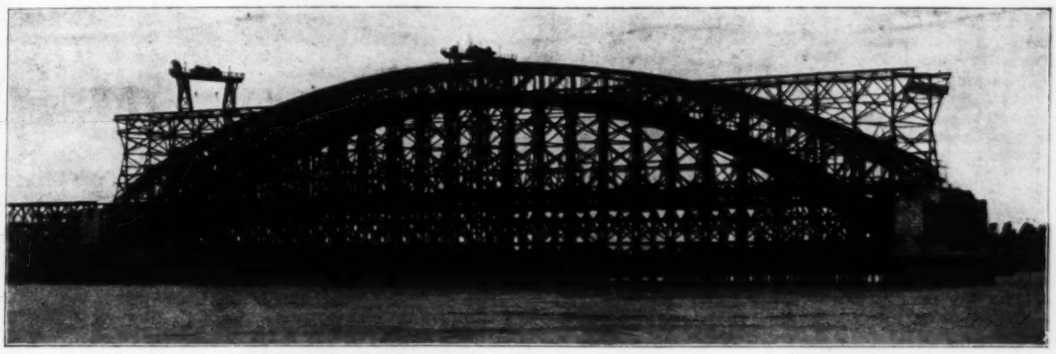


FIG. 17.—FALSEWORKS FOR ERECTING MAIN ARCH SPANS OF THE DUESSELDORF BRIDGE.

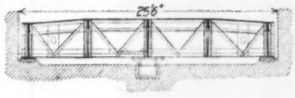


FIG. 4.—END FLOOR BEAM ON PIER, BONN BRIDGE.

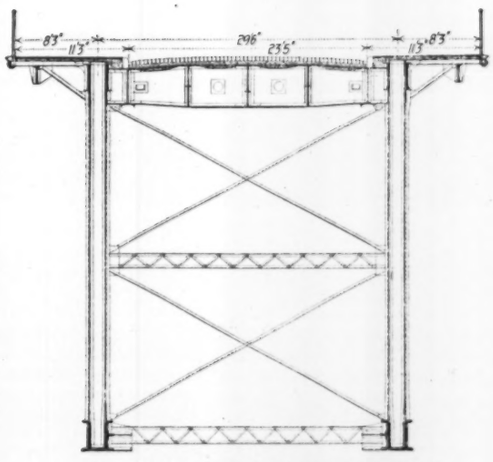
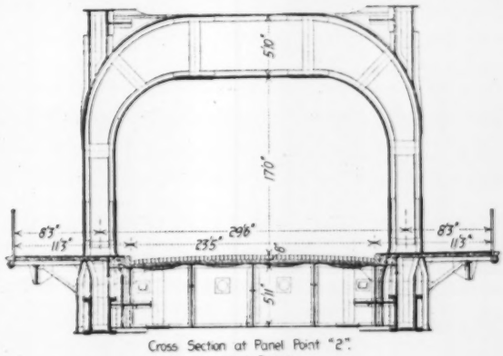
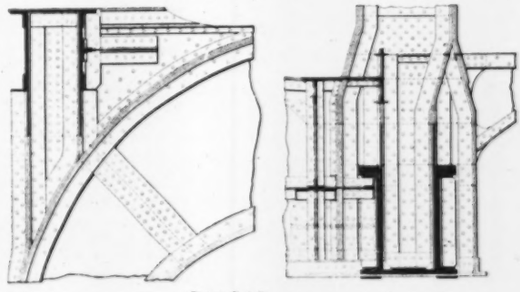


FIG. 2.—TRANSVERSE SECTION OF CENTER ARCH NEAR PANEL POINT O., BONN BRIDGE.



Cross Section at Panel Point "2". Showing Wind Portal.



Portal Details.

FIG. 3.—PORTAL CONSTRUCTION, BONN BRIDGE.

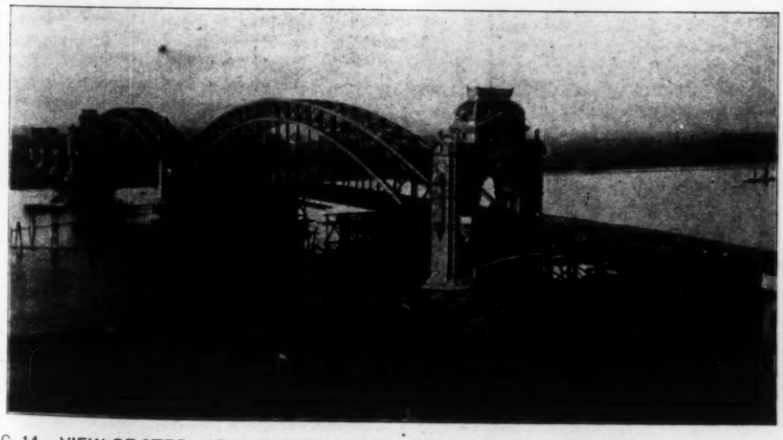


FIG. 14.—VIEW OF STEEL ARCH BRIDGE ACROSS THE RHINE, AT DUESSELDORF, GERMANY.

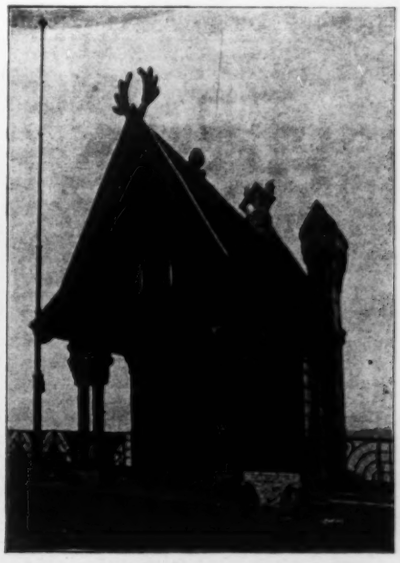


FIG. 10.—TOLL HOUSE FOR BONN BRIDGE.

published regarding the calculations upon which the works have been planned and carried out.

Going back to the question of original location, it may be well to remind our readers that in the earlier days of our railway history, and up to within less than twenty years ago, the location of railway lines was considered almost a branch of engineering in itself; in fact its relation to the operation of railways was hardly comprehended. There were, of course, certain limitations as to maximum grades and curves, but these were usually of a very arbitrary character, sometimes adopted before even the reconnoissance surveys were made. The effect of the distribution and arrangement of grades, curves, and other features upon train service and operating expenses did not enter into consideration, as a general thing. The engineer, and especially the locating engineer, thought it the end of his business to lay out a favorable and suitable line, and then, perhaps, to superintend its construction. Beyond that point he considered that his field did not extend.

It was in those days that the opinion obtained that locating engineers, like poets, were "born, not made," and much was heard of the wonderful powers of a man with "an eye for country." Location was regarded as something mysterious, and the idea scarcely existed that it could be analyzed on a scientific basis, and its principles made comprehensible to any man. We by no means intend to say that there is nothing in an "eye for country," or that one engineer is as good as another for location purposes. Some men have greater intuitive perception of topographical conditions than others, and many of the old-time locating engineers unquestionably did good work in their day. The "born" locating engineer, however, was apt to consider himself superior to considerations of mere scientific and economic principles. Had he but understood them, the quality of his work might have been of vastly higher grade. He was also apt to be ignorant of, or regardless of, the operating conditions which might be affected by his work. On the other hand, a good bridge engineer or municipal engineer might make a poor hand at location, but if he had carefully studied the latest and best information on the subject, he would probably have a better basis upon which to work than if compelled to rely upon his "eye for country" and his general knowledge of surveying and engineering.

The work of the "practical" locating engineer, as opposed to the scientific engineer, is evident on many of our railways, and has in many cases compelled railway companies to incur large expenditures for improvements in their lines in order to facilitate the handling of traffic. Not all the changes and improvements in our railways are due to such a cause. Many of them are due to the fact that the roads were located and built at a time when railway engineering was in its infancy, many of the underlying principles then remaining undiscovered, and when it was impossible to foresee the future conditions of traffic. Much of the important work of the locating engineers of recent years has been the designing of improvements in existing lines, based upon traffic conditions, the problems including factors never dreamed of in the days when the main study of the locating engineer was to put a line through without exceeding a certain grade. Even in quite recent years traffic conditions have been generally looked upon as entirely foreign to questions of location.

Difficulties in operation are pretty sure to arise upon a line whose locating engineer failed to look beyond the construction, and where the questions of keeping within the prescribed limits of grade and curve, and of keeping the cost of construction as low as possible, have been regarded as of prime importance. As a matter of fact, the most important feature of railway location is its influence upon the operation of the railway when built. The effects of a location which is disadvantageous in this respect will be felt severely in the future, either by the continual expenses and difficulties of operating, or by the expenditures of large sums to improve the original conditions. Two important problems which frequently enter into consideration in regard to operating and economic conditions, are as follows: (1) The comparative advantages of a long developed surface line (permanent or temporary) and a shorter tunnel line involving heavy work; (2) the comparative merits of a line with cheap structures which must subsequently be renewed, or one built with substantial structures at the beginning.

In the book of engineering rules of the Northern Pacific Ry., it is pointed out that in location the aim should not be to secure a line of uniform low cost, but one of least total cost. It is a common error to reject routes with short sections of heavy and expensive construction, in favor of more uniform (although inferior) routes of greater total cost. We cannot refrain from repeating the following rule, which indicates that when location is apparently easy it is apt to be carelessly done, with the result that it may give a very expensive line:

The possibility of obtaining a very good line should not preclude the search for a better one. The greatest and most costly location errors occur most frequently in prairie regions.

In regard to the tendency in practice to introduce timber trestles (not required for waterways), in order to save time or to avoid difficulties in building embankments, it is explained that the maintenance cost of such structures is far in excess of that of embankments of equal first cost. The rule is therefore given, that such a structure should not be built unless the cost of an embankment exceeds both the first cost of the bridge and the subsequent cost of filling it in. The Northern Pacific Ry., like most of our great western roads, has had a large amount of temporary work, and has spent much time and money in filling trestles and effecting other improvements. Whether these structures might, to some extent, have been avoided in first construction, under the economic and financial conditions then existing, we are not prepared to say. Rapidity of construction was then a prime consideration, and it is probable that in many cases problems were solved in the quickest and easiest way, rather than studied out with a view to future conditions, with which the engineer perhaps conceived that he had little to do. At any rate, it is evident that the Chief Engineer of the Northern Pacific Ry. intends that in the location and construction of future extensions such problems must be worked out upon an economic basis.

In this connection we may refer our readers to the profiles of transcontinental roads which were given in our issue of June 10, 1897, with some discussion upon their general features and the arrangement of their grades. In that article it was stated that the Great Northern Ry. gets through the mountains with an easier profile than that of the Canadian Pacific Ry. This is true as far as the mere question of grades is concerned, but from an operating point of view the Canadian Pacific Ry. has far the better location. The heavy grade sections of the former road cover a distance of 650 miles, while the heavy grades of the latter are bunched in one operating section of 125 miles, and westbound trains have but one lift, and eastbound trains two lifts. By reason of this concentration of heavy grades, it is claimed that for a corresponding distance from the Pacific coast this road can move a given amount of tonnage with a smaller expenditure of power than can be done on any other of the transcontinental lines. Our attention has also been called to the fact that while the two roads have total ascents of 15,305 ft. and 23,051 ft., respectively, these figures are for distances of 1,780 and 2,906 miles. Comparing the routes from St. Paul to the Pacific by the Great Northern Ry., and the Soo Line and Canadian Pacific Ry., the latter has nearly 3,000 ft. less elevation than the former. Similar results are obtained from a comparison of the main line of the Great Northern Ry. with that of the Canadian Pacific Ry. for equal distances from the Pacific Coast.

In closing, we may refer to one more point, that of short direct routes as compared with longer but easier routes between the same points. In several cases, undue importance has been attached to directness of route, without consideration of operating conditions. In the article on "Notes on Colorado Railways," in our issue of April 6, reference was made to a particular case in which a short direct route is far inferior to the roundabout route. The late Mr. Louis de Busschere, Engineer-in-Chief of the Belgian State Railways, published only a short time before his death, a pamphlet on "Virtual Lengths of Railways," discussing the difference between the actual length in miles, and the virtual length as affected by conditions of grade and curvature, with their influence upon the speed. His discussion was more particularly in regard to high-speed lines, and showed that a line of shorter actual length might be unable to compete economically with one of shorter virtual length, owing to the unfavorable conditions under which the former had to be operated.

LETTERS TO THE EDITOR.

Colorado Railways.

Sir: In reference to the article on Colorado Railways in your issue of April 6, I would call your attention to an error concerning the Colorado Midland Ry. This line runs from Colorado Springs to Grand Junction, and does not use the "D. & R. G. tracks" from New Castle to Grand Junction, as stated in your article. The error probably occurred from the fact that the line from New Castle to Grand Junction is a separate and distinct road, known as the "Rio Grand Junction Railway," the ownership of which is equally in the hands of the Colorado Midland Ry. and the Denver & Rio Grande Ry., and is used jointly. Yours truly, W. F. Bailey,

Gen. Pass. Agt., Colorado Midland Ry.

Denver, Colo., April 11, 1899.

Railway Location and Operation.

Sir: I have read your article ("Colorado Railways") in the Engineering News of April 6 with great interest, although I have not had the opportunity to become familiar with the lines by personal experience. You have compiled much valuable data, but it is hardly sufficiently complete to permit the reduction of their relative operating values to a common denominator. I find this difficulty continually appears in all physical descriptions and statistics regarding the characteristics of the line.

The Interstate Commerce Commission requires a vast amount of information that is absolutely useless for all practical purposes, and I have a number of times thought how much better this wasted labor could be employed in compiling data that would serve as a real basis of comparison of the relative operating merits of different railways.

The profiles which you present are little short of a nightmare, and not only show severe topographical conditions, but, in addition, a lack of comprehension in the original location of the lines, of the real elements affecting the cost of operation. Yours truly,

E. H. N. P.

St. Paul, Minn., April 11, 1899.

Capacity of Dump-Carts.

Sir: The capacity of an ordinary one-horse tip-cart is given by Trautwine and others at about ⅛ cu. yd., measured in the bank, and most of these authorities quote from experiments of Ellwood Morris, which were made in 1841.

I have had occasion recently to take observations upon quite a number of jobs in New England, and have found that the capacity of a cart varies widely with the character of the material, but that an average load is 15½ cu. ft., measured in bank. The cubic capacity of the carts, water measure, that is, the net measurement of an empty cart, averages 18 cu. ft. My notes upon the capacity of a two-horse tip-cart show an average of 28 cu. ft., measured in bank. I am unable to account for the discrepancy between these results and those given by Trautwine, and should like very much to hear from engineers and contractors who have had occasion to make notes upon the subject. Yours very truly,

Sanford E. Thompson.

Newton Highlands, Mass., April 17, 1899.

Engineering Notes in Porto Rico.

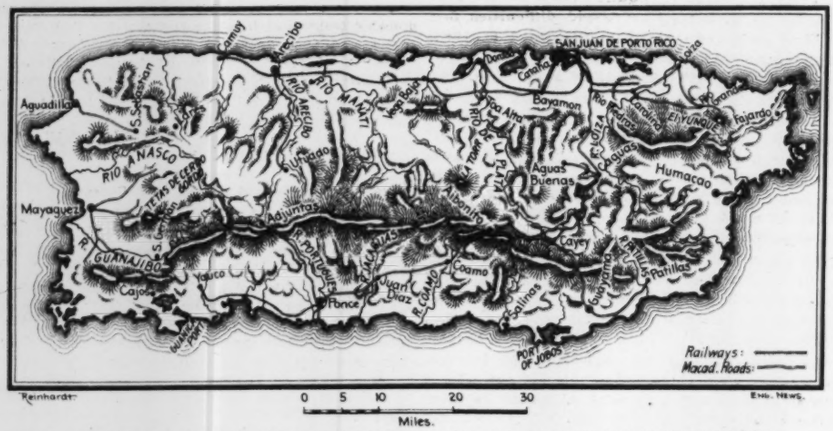
III.

Sir: I had to close my last letter rather abruptly and without completing my description of the country between San Juan and Aibonito. The whole country on both sides of the road and far back into the interior is very well inhabited and very thoroughly cultivated. The steepest mountain slopes are cleared of timber and under cultivation to their very summits. The chief product of this region is tobacco, which grows luxuriantly everywhere up to elevations of 1,000 ft.; above that height the entire country is covered with coffee, and as certain classes of shade trees are grown with the coffee to protect it from the sun's rays, the country has the appearance of being forested, whereas the contrary is the case. In the flatter regions, along the river bottoms, as in Caguas valley and in the vegas about Cayey, there are great fields of guinea grass, a luxuriant forage plant on which

large herds of cattle are fed. It will thus be realized that there is considerable business awaiting proper transportation facilities. At present everything is moved from the fields on pony back in panniers to the main military road, and often along this to the principal cities. On the military road it is hauled in two-wheeled bullock carts from the stores, where it is sold by the farmers, to the ports of San Juan and Ponce.

The water supply is sufficient to generate such amount of electric power as might be necessary for the propulsion of electric cars. The minimum discharge of the various small streams is rarely below 25 cu. ft. per second. The Rio Caguacitas discharges as a minimum 50 cu. ft. per second; the Rio Loiza the same, and the La Plata twice this amount. As all these streams come from the mountains within but a short distance of the road, the height of fall is great. It is not unlikely that heads of from 100 to 500 ft. can be found on nearly any of these streams for the generation of power through Pelton or turbine wheels.

Leaving Aibonito the entire aspect of nature changes suddenly, as the descent from the summit to the south coast is commenced. The evidences of the diminished precipitation are to be seen on every hand. The vegetation is no longer the brilliant emerald hue seen on the north coast. The nearer one approaches to the coast at Ponce the more parched and dry it appears. This is due not only to the smaller amount of precipitation, but is also in part due to the character of the soil. This has come from the disintegration of a different geologic formation from that of the north slope, and is no more the unctuous red clay seen on that side. It is more sandy and gravelly, and resembles to a greater extent the soil seen on the hills in Southeastern New Mexico and Southern Colorado. The vegetation has something of the appearance of that region; the grass is no longer the tall, juicy guinea grass, but short, dried grass, not unlike the gramma grass of Arizona; cactus, maguey, Spanish bayonet, yucca, etc., are among the prevailing flora, while trees of the acacia family, similar in general type to the mesquite of the Southwest, are abundant.



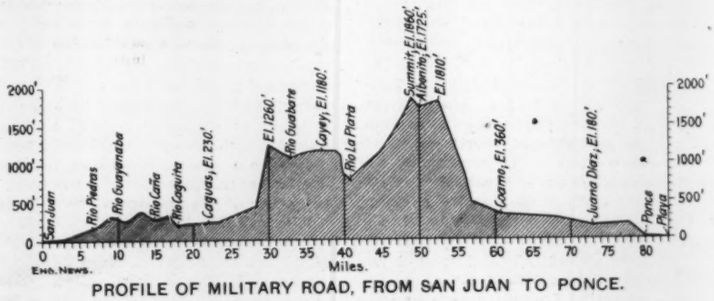
MAP OF PORTO RICO, SHOWING RAILWAYS AND MACADAMIZED ROADS.

As a result of the semi-arid conditions existing here, irrigation is largely resorted to for the cultivation of sugar, the staple crop of the coast lands. Coffee is extensively grown as everywhere on the island, above 1,500 ft. Between that elevation and the low coast country, which is reached at Coamo, elevation 360 ft., the agriculture is of a mixed kind, some tobacco being produced, oranges and bananas being grown and other smaller fruits and vegetables. The lower hills from above Coamo to the coast are fairly covered with short forage grass, and quantities of cattle are grazed upon this. In the smaller valleys among the coast hills and in the various playas or alluvial plains which are found about the mouths of all the rivers, sugar cane is the staple crop. The irrigated cane which I saw is of enormous size, the stalks being as big around as a man's arm and from 12 to 15 ft. in height. The most important evidences of irrigation were encountered just between Juana Diaz and Ponce. There, a number of ditches, of considerable size are diverted from the Jacaguas, Inibon, Bucana and Portugues rivers. That from the first is diverted in the hills about five miles above the military road. It is 5 ft. wide by 3 ft. in depth, and is well graded around the hill slopes, reaching the level sugar lands at a sufficient height to give good head. A typical Spanish-American wing dam for diverting water was seen on one of these streams, consisting of a mass of loose rock and boulders thrown out in the stream. This diverted the water into the head of the ditch, the latter being a substantial work of the best masonry construction. On these ditches are occasionally seen aqueducts and some training works to protect them from the erosive action of the streams from which they are diverted. These are always of the most substantial masonry, and designed to stand for all time.

This country is an ideal one for irrigation; its water resources have scarcely been touched, and they permit of great future development. The agricultural possibilities, except in the matter of sugar growth, are also largely undeveloped. The land consists of gently sloping hills and easy sloping plains, offering the best conditions for the construction of irrigating ditches. The soil is of that deep porous texture which admits best of irrigation because it furnishes excellent natural underdrainage. The water supply is abundant and well distributed, good sized streams being encountered in every few miles. A large proportion of the minimum discharges of these streams is being utilized, though rather wastefully. The opportunities for storage and for irrigation from flood discharge both appear to be good.

The road from Aibonito to Ponce leaves the summit at kilometer 85, with an elevation of 1,810 ft., and descends even more abruptly during the next 7 kilometers to an elevation of 480 ft., than it ascends on the north slope from Cayey to Aibonito summit. This descent is made in such a short horizontal distance, only about three miles in an air line, that in order to maintain a moderate grade the road twists and winds among the hills and about the spurs in the most picturesque manner conceivable. It reminds one much of the roads found in Switzerland in ascending some of the celebrated passes. In one place, in a distance of about 500 ft. horizontally, the road makes three loops, great masses of the hillside being excavated on the upper side, while the lower side is sustained by massive retaining walls of masonry. Near Coamo the low foothill country of the south coast is reached, and thence the grade is very easy, from elevation 360 ft., at kilometer 98, to Ponce Playa, kilometer 134, which is at the sea-level. Throughout this portion of the road the construction is simple; there are numerous long tangents and little heavy excavation of filling. All of the streams are crossed, however, on substantial bridges with masonry abutments and piers, though the spans are often of plate girders. The only exception is the Rio Portugues at Ponce, which has to be forded.

Some interesting evidences of the recent conflict with Spain and the work of the volunteer engineers were seen between Aibonito and Juana Diaz. There are two or three bridges here which were blown up by the Spaniards as they retreated to their entrenchments on Aibonito summit. These were at once rebuilt by the army engineers, under fire, and two of them are well constructed of masonry and look quite as substantial as do the other bridges built in time of peace by the Spaniards; they are especially creditable in view of the conditions under which they were rebuilt. Another is a fairly substantial wooden structure of timbers, of the usual trestle type employed in hasty American construction, the timbers having been brought down with the army. This will undoubtedly have to be replaced soon or the floods will surely carry it away. At present it serves its purpose well.



PROFILE OF MILITARY ROAD, FROM SAN JUAN TO PONCE.

One of the most interesting pieces of engineering in the way of a military road is the branch of 17 miles from Cayey to Guayama. This road has but recently been built by the Spanish. It is a magnificent piece of alinement and grading, and is even more substantially bridged and maintained along the mountain sides and better surfaced than the main military road. A few miles out of Cayey it crosses the main summit at an elevation of 2,450 ft.; five miles beyond, it crosses a second pass at an elevation of 2,100 ft.; thence, in 7¼ miles, it descends to Guayama, elevation 180 ft. Into this 7¼ miles, in which 2,000 ft. of elevation are overcome, is condensed some of the most magnificent scenery and most difficult highway construction that is to be seen anywhere in the world.

Ponce is the commercial city of Porto Rico, and it is in no wise fortified or protected by city walls as is San Juan. In fact, San Juan is the only fortified city of the island. Ponce proper is about three miles from the seaport or "Playa," as it is called, and it is connected with the latter by the continuation of the main military road. Half way between the two is a long bridge spanning the Rio Portugues. This is a temporary structure of wood, which replaces a more substantial bridge which was destroyed about ten years ago by a great flood which visited this portion of the island. Since then the Spaniards have not made any attempt at the construction of a permanent bridge on this thoroughfare.

Ponce is a business and residential city of about 22,000 inhabitants. The streets are badly paved, in fact not nearly so well paved as those of several of the smaller cities, and in no way to be compared with those of San Juan. The main street, along what may be considered the line of the military road, is macadamized; the remainder of the streets are chiefly surfaced with gravel and dirt. In fact, on this, the arid side of the island, macadamizing and paving is not nearly so much resorted to in the cities, good dirt roads last fairly well because of the lesser precipitation. The dirt streets of Ponce, however, are not creditable nor are they clean. Refuse, in the form of garbage and offal, is to be seen in the gutters and streets, and streams of sewage and foul-smelling water are to be seen flowing through the gutters and even across the streets. A number of rats caught in the house in which I am boarding were thrown into the street before the day of my arrival, and after a week's exposure to the tropic sunshine they have not yet been removed. Yet this is on the main thoroughfare leading to the Playa and but one block from the plaza.

The sewerage, or rather the lack of it, is of the same kind as has been seen everywhere else. Storm water is carried off by surface drainage; all sewage is either discharged into the streets, or more commonly into the usual cesspool in the central court; there is no garbage collection nor is there any organized system of street cleaning as in San Juan. Fortunately for this, as for many similar cities on the island, water is but sparsely used, chiefly because of the lack of proper city water supply, and consequently such smaller amount as is used for domestic purposes can be accommodated by the cesspool, and is therefore not discharged to any great extent into the streets. These cesspools and the interiors of the buildings are, accordingly, the breeding places of pestilence in this city as in San Juan. No one who has any regard for sanitary laws will think of occupying a room facing upon these interior courts, yet the average Porto Rican and Spaniard think so little of such matters that an interior room is quite as acceptable to them as one facing on the outer streets.

The water supply of Ponce is fairly good, as it is a gravity supply received from the Rio Portugues. It is piped for about 8 to 9 miles in covered masonry conduits to a large receiving reservoir on the top of the hill back of the hospital. This reservoir is covered, and from it the water is carried underground in iron pipes into the

city. The distribution system is, as elsewhere, of the most inferior character, water being piped to but a few houses on the main streets.

There is no engineering work of any interest in or about the city of Ponce. There are electric lights in the streets as in San Juan, and, for that matter, as there are in a number of the smaller cities passed on the military road between the two places. The harbor of Ponce Playa can hardly be called such; it is little more than an open roadstead, with one or two islands interposed between the open sea and the indentation in the coast, which is dignified by the name of "port." Ships have to anchor at distances of half a mile to a mile from the shore and are unloaded and loaded by lighters. These lighters are hauled up to the beach in front of the various warehouses, and are chiefly unloaded on the backs of men, who stand waist deep beside them in the bay. There are two or three fairly good piers, the principal one being the government wharf, and to these the lighters can tie up and unload when the sea is not too rough. This, however, is rarely the case, the swell being usually so great as to make it difficult to land even from a rowboat. It is curious that so important a commercial city, and one at which all the steamship lines as well as merchant vessels stop, should be so poorly provided with modern facilities for handling cargo.

But a few miles from Ponce to the eastward is a magnificent natural harbor, the port of Jobos. This is now being surveyed by the Coast Survey steamer "Blake," and it is believed will prove with a little dredging to be the best natural harbor on the island. Already there are one or two enterprises on foot for developing there a typical American boom city in anticipation of its being one of the future commercial ports. There is an interesting project at this point for the diversion of the Rio Plata, which flows to the north coast, through a short tunnel, which will discharge it toward the south coast, where it may be utilized in the generation of power and in irrigation in and about Jobos port and Guayama city. About an equal distance to the west of Ponce is the port of Guanica, at which General Miles landed with his first expedition, and which likewise gives promise of becoming, with some little work, a harbor superior in all respects to either Ponce or San Juan.

To-morrow I set out over the military road and the temporary road built by General Roy Stone to Adjuntas, and thence by trail to Utuado, Lares and Mayaguez. While expecting to see little of engineering interest on this journey, I hope to learn much of the interior transportation facilities of the island and of the necessity of and opportunities for their improvement. H. M. W.

Ponce, Porto Rico, Feb. 14, 1899.

Notes and Queries.

The use of salt to prevent hydrants from freezing, noted in our issue of March 16 as a suggestion from Mr. Frank Schefold, of New Albany, Ind., is considered as bad practice by Mr. John Link, Chief of the Fire Department of Newport, Ky. Mr. Link, who also speaks from an experience of 25 years, says salt will destroy the valve seat and bottom of the casing. He prefers to use a frost jacket, and remarks that he has perfected such a device, which has been used with success.

ANOTHER METHOD OF WIRELESS TELEGRAPHY which differs radically from the system developed by Hertz, Lodge and Marconi is credited to Prof. Zickler, of Brunn, Moravia. This system depends upon the sympathetic relation between electricity and the "ultra-violet" rays of the solar spectrum. The apparatus employed consists of a transmitter provided with a spark gap between the terminals of which a shower of small sparks is allowed to play. Ultra-violet rays precede from this arc and are collected and concentrated by a reflector and an arrangement of quartz lenses. The invisible beam thus formed is projected towards the receiving instrument, which resembles the transmitter, except that the terminals consist of a small platinum-covered sphere and a round, flat plate, which also serves as a reflector and concentrates the incoming ultra-violet rays on the small globe. The terminals of the receiver are too far apart for the current of the receiver circuit to spark across, but under the influence of the concentrated beam sparking occurs and the flow of current thus established instantly operates the local or relay circuit, which produces a visible or audible signal corresponding in duration to the time the screen of the transmitter was out of the beam. In this way Morse signals can be transmitted. So far the system has been purely experimental and the distance covered has been limited to a mile.

A NINTH SATELLITE OF SATURN has been discovered by means of the Bruce photographic telescope, at the Harvard observatory at Arequipa, Peru. The eighth satellite was also discovered by Harvard astronomers in 1848. The new satellite is of the 15.5 magnitude; the span of the orbit is about 15,750,000 miles and the time of revolution about 17 months. It is approximately 7,875,000 miles from the planet's center, or about 3½ times that of Iapetus, formerly the outermost satellite. It is so faint that without the photographic plate it probably would not have been noticed.

RULES FOR RAILWAY LOCATION AND CONSTRUCTION; NORTHERN PACIFIC RY.*

Construction and Engineering Departments.

Organization.

The Construction Department will have charge of all surveys and construction in connection with the building of new railways or extensions of existing lines.

The Engineering Department will have charge of all surveys and engineering connected with the work of improving lines already built.

The organization of the Construction Department will be as follows: (1) Chief Engineer, reporting to the President. (2) Division Engineers, with jurisdiction as assigned by the Chief Engineer. (3) Assistant Engineers in charge of the construction of a line, or other work of importance, reporting to Division Engineers. (4) Locating Engineers, reporting to Division Engineers or to Assistant Engineers as directed. (5) Resident Engineers, in charge of the construction of a section of new road, or a subdivision of some work, reporting to Assistant Engineers. The organization of the Engineering Department will be as follows: (1) Chief Engineer, reporting to the General Manager. (2) Division Engineers, having charge of the engineering work upon lines in operation, reporting to the Chief Engineer, and also acting as Division Engineers of the Construction Department upon special assignment by the Chief Engineer to such work. (3) Assistant Engineers, in charge of special work, reporting to Division Engineers.

The duties of the Engineering Department will be as follows:

1. To secure and maintain records of the physical characteristics of the railway, including roadbed, track, ballast, bridges, culverts and other structures. The records should show number or quantity, location, type, dimensions, condition, cost and date of construction, in all necessary details.

2. To make general inspection of all such structures annually, and such other examinations in special cases as may be necessary at all times; to furnish reports on their condition, and estimates and recommendations covering repairs, renewals and replacements in the manner and on the forms prescribed.

3. To prepare and maintain correct station and right of way plats, standard track and other profiles, standard maps and plans, and all general engineering records.

4. To supervise and direct all work of special character, as assigned by General Manager and Chief Engineer.

5. To inspect and report condition of all ordinary and special work to insure compliance with standard plans and specifications.

6. To prepare plans, specifications and estimates for all duly authorized work, when necessary, to prepare forms of proposal and contracts for such work, and to award contracts when approved by the General Manager.

7. To furnish all necessary stakes, centers, elevations, cross sections and measurements required for the execution of routine or special work, and otherwise to aid and supplement the Division forces to the best advantage of the railway company.

Engineers will have no authority over roadmasters, bridge foremen or any regular force of the several Division Superintendents, except as it may be conferred upon them in special cases by the General Manager, General Superintendent, or Superintendent, but they must report to the proper official any neglect or failure to execute work in accordance with the duly authorized plans, specifications or instructions governing such work.

None other than routine work will be undertaken without formal and sufficient authority, confirmed by approved Improvement forms (1363), or by special direction of the General Manager, General Superintendent, or Assistant General Superintendent transmitted through the Chief Engineer or the Division Engineers.

No work affecting safety or regularity of trains must be undertaken without previously notifying the Superintendent of the Division upon which the work is to be performed, and the subsequent execution of the work must conform to the orders, rules and regulations established by the Superintendent to insure safety.

All necessary track or bridge work in connection with such work will be performed by the division force, under the instructions of the Superintendent or his roadmasters or bridge foremen.

Salaries and wages of special forces employed under the direction of an engineer, unless specially excepted, will be carried on the Superintendent's rolls, the engineer making time returns in the manner prescribed by the standard rules in force on the Division.

Before the beginning of each season's work Assistant Engineers will be furnished with a list of the various improvements authorized. The limits within which track laying and ballasting are to be prosecuted should be ascertained in advance and levels run over such sections and profiles sent to the Division Engineer, plotted to a double vertical and single horizontal scale. The Division Engineer will locate the proper ballast grade line and Assistant Engineers will compute quantities in cubic yards of material required for bank widening, raising sags and ballast.

At the close of each season's work Assistant Engineers will furnish a detailed report of the various improvements completed, giving full notes and sketches wherever necessary.

Location. (Theory.)

"Engineering is the art of making a dollar earn the most interest."

A railway is a commercial enterprise and is constructed solely for profit.

The factors affecting profits are: 1. Gross earnings. 2. Operating expenses. 3. Fixed charges. The effect on such factors, of differences of route, location details and construction cost must be determined before the final route of least cost and greatest value can be fixed.

The combined sum of operating expenses and interest charges is least when interest charges on additional expenditures are no longer saved in reduced cost of operating expenses, and when additional operating expenses are no longer saved, in reduced interest charges. Accordingly, the economic value of each factor affecting the cost of operating must be ascertained and carefully compared with its corresponding effect on construction cost, in order to secure the most economical ratio between operating expenses and construction cost.

The principal factors affecting cost of operation, with which the Engineer has to deal, are: Volume of traffic, gradients, distance, rise and fall, curvature and maintenance of railway, for which economic values are elsewhere given under appropriate heads.

The sums which may be profitably expended for improving the character of the railway location and construction vary most directly with the number of trains to be operated over the new railway, for which reason the "train mile" is usually adopted as the operating unit. The commercial effectiveness of "operation" is reflected in the average cost of transportation per net ton mile, which may be regarded as the commercial unit.

The least cost of transportation is secured when the lowest train mile cost is combined with the largest net tonnage per train. And the earning power of the invested capital is greatest when least cost and greatest net tonnage per train are combined with the lowest economic capital expenditure.

Under these conditions only does "a dollar earn the most interest."

General Instructions.

The rules governing location are intended for use in the field, and it is expected that they will be closely followed. The ability of the engineer will be determined by this standard.

Before any new road is located, the Chief Engineer will indicate the character and purpose of the line, and will give the number of trains for which the line is to be located. After the completion of the preliminary surveys he will also determine the rates and proper adjustments of the ruling grades and the maximum degree of curvature to be adopted. All locations must be approved by the Chief Engineer before construction is begun.

Each railway location should be specially considered with reference to its effect upon receipts, operating expenses, and fixed charges, the character and direction of the expected traffic and the class and number of trains to be operated over it. The selection of route, adjustment of location details and character of construction will be determined in accordance with the ascertained conditions of lowest operating expense and least construction cost for each case.

Locating engineers will furnish weekly reports, stating progress and giving all other items of general interest pertaining to their work, especially information concerning present or prospective sources of traffic, its locality character and amount.

Strict compliance with the instructions is expected concerning the preparation of maps, profiles, records and estimates.

Graphic tables for computing quantities on transverse slopes for use in preliminary estimates will be furnished by the railway company.

So far as practicable, all maps, profiles, estimates and general records will be completed while the surveys are in progress, avoiding all unnecessary accumulations at the close of the work.

Competent engineers will avoid much unnecessary loss of time and money by making preliminary reconnoissances in person, using pocket compass, hand level and "aneroid" when necessary. When there are several alternate routes careful examination will usually prove it unnecessary to make instrumental surveys over them all.

Rapid exploration lines, especially when in timber, should be run with compass bearings; in many cases the method of stadia readings will also expedite progress. The time-honored custom of conducting explorations from behind the transit should be changed for a more intelligent method.

The reconnoissance should be of an area rather than of a consecutive line, all lines or combinations of lines connecting controlling points being studied as a whole. It should be the effort of the engineer to first ascertain the position, character and limiting effect of controlling points, natural or otherwise; afterwards connecting such points most ad-

*From the Engineering Rules and Instructions of the Engineering and Construction Departments of the Northern Pacific Ry." issued Jan. 1, 1899. Mr. E. H. McHenry, M. Am. Soc. C. E., Chief Engineer.

vantageously, and finally filling in intermediate details to the best advantages.

No local conditions of rocky slopes, swamps, brush, timber, etc., should be allowed to unduly influence the Engineer as to their real effect upon the total estimate. He should also remember that alternate lines will be compared upon the basis of completed cost, and not on the cost to subgrade only, and finally that it is not the object of location to secure a line of uniform low cost, but of least total cost. It is a common error to reject routes with short sections of heavy construction cost in favor of more uniform although inferior routes of greater total cost.

The route of best grades and alinement should always be first projected, working back to the final and most economical route. Working in the reverse order usually results in inferior location.

The possibility of obtaining a very good line should not preclude the search for a better one; the greatest and most costly location errors occur most frequently in prairie regions.

Valley locations are usually projected from "point to point" on the line of shortest distance, when the stream is unimportant, otherwise the convex angles of the stream on one side and the slopes on the other form controlling points, if not modified by the additional latitude of choice afforded by the two sides of the stream, or any combination of same.

Bench, plateau or prairie locations are usually projected on routes of most uniform grade and direction between controlling points. Commercial centers, stream crossings and controlling elevations form the principal controlling points.

Mountain locations are subject to greater restrictions, and are usually fixed with reference to the position and height of the summit, the distribution and amount of rise and fall to be overcome and the relation between the adopted gradients and the corresponding length and cost of line.

The summit is, of course, the principal controlling point; other points are generally accidental or artificial, as determined by local topographical conditions and the rate of grade adopted for the descent. Such lines are usually located descending from the summit along a uniform grade contour to an intersection with the "bottom" line of lower grades.

All locations should be made with regard to future permanent construction and every effort used to reduce the amount of temporary construction which may be required to the least limits. Many opportunities for stream diversion are neglected, even in cases where the cost of the bridging otherwise required is many times in excess.

When construction funds are limited, adopt lower standards of construction, lay temporary gradients and use short sections of temporary line around or over tunnels and sections of heavy work, if necessary to avoid sacrificing future benefits arising from a properly located route. Such lines may be economically revised at some future time, while the revision of a generally faulty "location" might involve such large expenditure as to make a remedy forever impracticable.

Exercise extreme care in fixing the locations for stations, water tanks, coaling plants and crossings, and in adjusting grades for same, to reduce the cost and disadvantages of train stops to the minimum.

Train stops on or near the foot of grades should always be avoided if possible, and when not avoidable for any reason, the rate of grade should be compensated to facilitate the starting of trains.

A proper reconnoissance report conveys a graphic impression of the features of the region and route traversed, and contains the fundamental elements affecting operation and construction cost. The engineer should separate the routes reported upon into natural divisions of similar characteristics, giving distances, grades and controlling points of each. He should describe, classify and approximately estimate the material to be moved and other work to be performed, giving averages per mile and totals for each section, and furnish an approximate estimate of the cost per mile and total cost of the completed railway. Small scale maps and profiles showing general features, elevations and distribution of ruling grades should accompany such reports, whenever necessary.

The fundamental principle of good location is common sense.

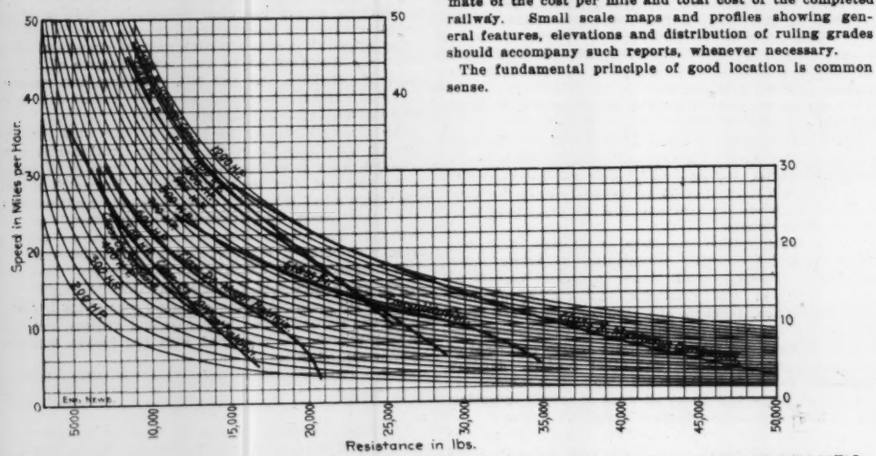


FIG. 1.—CURVES SHOWING HORSE-POWER OF STANDARD LOCOMOTIVES; NORTHERN PACIFIC RY.

Table of Mean Cylinder Tractive Power.

Speed in miles per hour.....		Initial speed..... / Terminal speed.....	45 / 10	40 / 10	35 / 10	30 / 10	25 / 10	20 / 10	15 / 10	10 / 10
Class X.....	Mastodon compound. Weight on drivers 150,000 lbs. " eng. & tendr, 270,720 lbs.		.....	.....	.....	23,607	26,094	29,050	32,433	36,000
Class P.....	10-wheel compound. Weight on drivers, 112,000 lbs. " eng. & tendr, 249,500 lbs.		16,057	17,071	18,219	19,521	20,947	22,432	23,917	25,400
Class R.....	10-wheel compound. Weight on drivers, 126,000 lbs. " eng. & tendr, 264,530 lbs.		15,575	16,618	17,819	19,212	20,822	22,545	24,267	26,000
Class F 1.....	Consolidation. Weight on drivers, 135,000 lbs. " eng. & tendr, 227,600 lbs.		.....	.....	.....	.....	18,934	21,659	25,100	29,300
Class D 3.....	Mogul, Baldwin. Weight on drivers, 85,900 lbs. " eng. & tendr, 175,290 lbs.		.....	.....	.....	11,743	12,921	14,353	16,058	17,850
Class E 2.....	10-wheel, Baldwin. Weight on drivers, 76,700 lbs. " eng. & tendr, 117,700 lbs.		.....	.....	8,942	9,755	10,653	11,664	12,800	14,050
Class C 2.....	Standard. Weight on drivers, 55,500 lbs. " eng. & tendr, 154,260 lbs.		.....	.....	.....	9,490	10,270	11,314	12,690	14,500

Volume of Traffic.

Fixed charges are but slightly, or not at all, affected by variations in volume of traffic. "General" operating expenses are affected only by considerable changes of volume, while the more direct expenses of operation vary more or less closely with the tonnage or passengers transported.

The effect on cost of operation of the number of trains operated is much more direct, than of the actual number of passengers or tons transported, hence the effect on the cost per train-mile is used as the basis for all economic comparisons, and the actual cost per train-mile should be ascertained in all cases, when possible.

Under practical conditions, the first trains operated cost more, and additional trains cost less than the average cost of all.

The average cost per train-mile for the United States is probably not far from $1, and this amount may be used for convenience, when more exact data are lacking.

When the number of trains is affected without affecting the total cars or tonnage, the cost per train-mile added or saved, may be assumed at 60 cts. in default of more exact data.

The cost of assistant engine service, extra cost of heavier engines and of all other items affecting the cost per train-mile, under special conditions, must be added or subtracted from the train-mile cost first assumed (see Ruling Grades).

If better estimates of cost are not available, estimate assistant engines at $7,500 per annum (per day of 12 hours) and heavier engines in the ratio of 15% increase of cost per train-mile for doubling weights on driving wheels. The total cost of assistant engine service should be divided by the number of trains served.

Passenger trains are but little affected in number or length by some classes of rise and fall and gradients, and should be excluded in all such cases.

For the purpose of comparison capitalize the annual cost of train expenses at 6%.

Distance.

Minor changes not aggregating over two miles on an engine stage, do not usually affect train wages, nor track force; train expenses and renewals are slightly affected.

The capitalized value of this class of distance per daily train per annum may be considered as 25 cts. per ft. to which should be added its construction cost, at say $3 per ft., when the actual cost is not known.

Greater changes, but not adding to the number of engine districts usually increase both train wages and track force. The assumed value of this class per daily train per annum is 60 cts. per ft. ($3,168 per mile). The actual construction cost should be added to the total thus obtained.

Considerable changes, adding to the number of engine districts and the number of trains operated, should be valued in accordance with the ascertained cost of similar service under similar conditions, but otherwise may be valued on the basis of $1 per train-mile, equivalent to $6,083 capitalized value per mile of distance per daily train per annum, adding all construction cost of railway and extra equipment to the amount obtained by multiplying this sum by the actual number of daily trains (each way).

The effect of distance on receipts is sometimes most serious, and a still further sum must be added in such cases, when the effect is sufficiently tangible.

Curvature.

The cost of operating curvature varies with the angular degrees of curvature operated, and is but little affected by the length of curve radius.

The operating value of curvature per degree is assumed at $7 per daily train per annum, but to this should be added the commencial value of lost time, if any, and also all extra construction cost of rail-braces, tie-plates, spikes and guard rails.

Curves exceeding 14° per station should not be used without due necessity and usually require both guard and "hold-up" rails for safety.

A maximum curve, unlike a maximum grade, is not limiting and does not justify the use of similar curvature elsewhere on the same engine district.

All curves of 3° and over must be provided with terminal transition curves, changing 1° with each chord of 50 ft. On mountain lines this rate of transition may be doubled if necessary.

Curves less than 300 ft. in length will not be used.

The minimum tangents between reversing curves must not be less than the chord length of the transition curves; the minimum tangents between curves in the same direction must not be less than 500 ft.

Curvature on maximum gradients must be compensated at a rate not less than .04 ft. per degree.

Use standard rules for super-elevation of outer rail.

Rise and Fall.

The effect on operation of minor gradients and small undulations, within "velocity limits" is very small, and its capitalized value is assumed at $2 per ft. per daily train per annum (one way). Limiting curvature and train stops on grades of this kind will greatly increase the cost of operation, and should be avoided in any event.

The value of rise and fall on grades of considerable rise exceeding velocity limits, but not requiring use of brakes and sand, is $7 per ft. per daily train.

The value of rise and fall on grades requiring the use of brakes and sand is $22 per ft. per daily train, and $30 per ft. if on ruling gradients.

The limiting effect on train weights, of long sections of more or less continuous rise, may considerably exceed that due to maximum gradients. This effect occurs oftenest on valley lines with low ruling gradients.

Train weights may be limited either by ruling gradients which tax adhesion, or by time requirements, which tax the engine boiler.

The product of speed and train resistance is horse-power, and with fixed conditions of speed and engine horse-power, the train resistance is also fixed. Hence, the train weights over the division may be fixed by the average scheduled speed, and the engine horse-power at limits far below those fixed by ruling gradients. Under such conditions the average and not the maximum resistance controls the train weights.

Compute engine horse-power by the simple formula

$$P = \frac{R \times S}{375},$$

in which P is horse-power; R, resistance of total train in pounds; S, speed in miles per hour; and 375 a constant factor. (See Fig. 1 for horse-power of typical engines in use on the N. P. Ry. in 1898.)

Vertical curves are required on summits at all grade intersections not less than 50 ft. in length for each change of one-tenth in rate of grade.

In "sags" the rate of change should not exceed 0.05 ft.

per station. In theory, the rate of change should be such as to maintain equality between the rolling resistance and the "acceleration of gravity" of each car throughout the varying rates of speed.

Ruling Grades.

Grades which limit the maximum weights and length of trains, are termed "Ruling Grades." Maximum grades, which may be operated by heavier engines, or by assistant engines, are not necessarily ruling grades.

The economic value of changes in rates of grades is determined by the relative total cost and number of trains, required on each rate of grade to transport the same number of cars and tons. The practical rule is as follows: Multiply the daily number of trains saved or added by the ascertained cost per train-mile, by the length of the division in miles, and by the number of days in the year, the result will be the annual saving or added cost, resulting from such change in rate. To obtain the capitalized value, divide this result by the proper interest rate.

When actual values are not known, assume the rate of 90c. per train mile (see Volume of Traffic), which capitalized at 6% is $3,650 (one way only).

The cost of operating heavier engines, assistant engines and all other items of expense added or saved, should be computed in addition and capitalized, if necessary (see Volume of Traffic).

Every effort must be made to maintain the lowest practicable and economical rate of grade over the entire engine district.

When sections of high grade are unavoidable, it is frequently practicable to concentrate such "rise and fall" into short sections, which may be economically operated by use of assistant engines.

The ruling grade of each engine district should be adjusted with reference to those of the adjoining districts, or to conditions of local traffic, in such a manner as to avoid unnecessary "breaking and making up" of trains. When not practicable to secure this by grade adjustment alone a combined adjustment of grades and engine, weights will effect the same end.

The ratio of rates of ruling grades to each other at points of intersection should preferably be in proportion to the tractive powers of the available types of engines.

On sections of great rise and fall (mountain crossings, etc.) it should be the aim of the engineer to produce the maximum and minimum ruling grades to an intersection, if possible, and in any event to reduce the sections of different rates to the least number.

Ruling grades may be of different rates, but equal limiting effect, when adjusted for unbalanced volume of traffic.

Train stops on maximum grades must be compensated as fully as practicable, and not less than 3.5 ft. in any case. Compensation is not only provided for the increase in starting friction over rolling friction, but in addition to permit trains to acquire speed more rapidly. Train stops near the foot of a long grade are most limiting in this respect.

Virtual Grades.

The motion of a train represents stored energy, derived from the engine or gravitation, and, under appropriate conditions, the power of the engine may be in part absorbed in imparting speed to the train, or augmented by the surrendered momentum of the train.

When rolling and grade resistances exceed the applied force, motion is retarded and energy released in definite proportions, and conversely, when the applied force is in excess, motion is accelerated and energy imparted in like proportions.

The moving energy of the train at different speeds is given in Fig. 2 in terms of "Velocity Head," which is the vertical height, through which the train would be lifted, at each degree of speed by its momentum alone.

The engine tractive power is least at high speed and short "cut off," and greatest at low speed and "full stroke," as shown in Fig. 1.

The mean tractive power of these engines from different rates of speed to ton miles per hour is given by the table, Fig. 1, or may be deduced from the diagram on the same sheet.

The maximum available power for overcoming rolling and grade resistance is represented by the product of the train weight and its velocity head, added to the product of the mean engine tractive power, and the time or distance over which the power is exerted, illustrated, in short, in the effect produced by "taking a run at the hill."

Rolling resistance for trains at all speeds is given by Fig. 3, from which mean resistances between different rates of speed may also be readily computed.

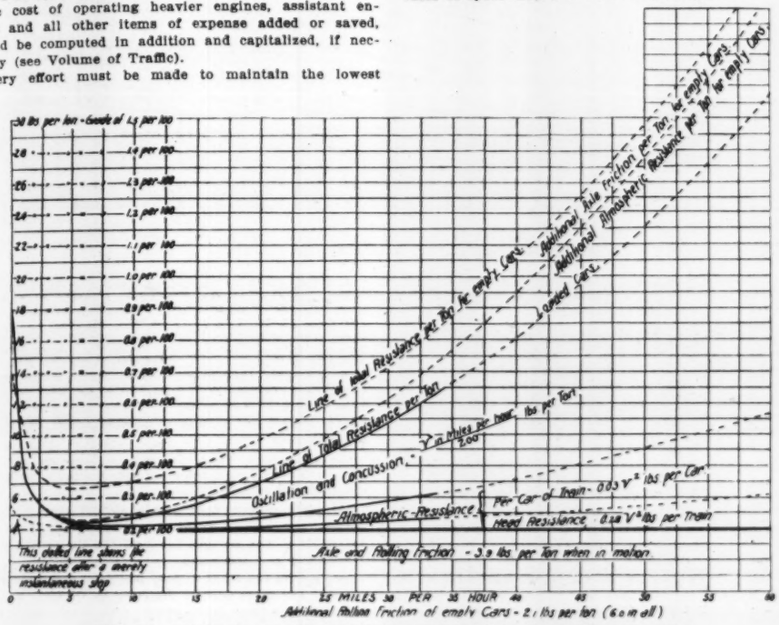

30 lbs per ton - Grade of 1.5 per 100
Additional Axle friction per Ton for empty Cars
Additional Atmospheric Resistance per Ton for empty Cars
Additional Axle friction per Ton for loaded Cars
Line of Total Resistance per Ton
Oscillation and Concussion
V in Miles per hour
Lbs per Ton
Per Car of Train - 0.03 V² lbs per Car
Atmospheric Resistance
Head Resistance - 0.28 V² lbs per Train
Axle and Rolling Friction - 3.9 lbs per ton when in motion
This dotted line shows the resistance after a severely instantaneous stop
25 MILES 30 PER 35 HOUR
Additional Rolling friction of empty Cars - 2.1 lbs per ton (6.0 in all)

FIG. 3.—DIAGRAM OF TRAIN RESISTANCE IN POUNDS PER TON.
(From A. M. Wellington's Railway Location.)

The simplest rule for computing grade resistance is as follows: Resistance (in lbs. per ton) = rate of grade (in feet) x 20.

A gradient of equivalent resistance to the force exerted by the engine is the "virtual grade," or real resistance taxing the engine cylinders. The virtual grade line may be plotted with the assistance of Figs. 1, 2 and 3, or computed in accordance with the general principles before given.

"Momentum" or velocity grades may be used with due caution to avoid increasing rate of ruling grades, or to avoid large construction expenditures otherwise necessary. In all such cases train stops, grade crossing and limiting or dangerous curvature must be avoided.

Velocity grades requiring freight train speeds in excess of 30 miles per hour must not be used, nor should such grades be laid out for speeds in excess of that obtainable under ordinary working conditions.

Maintenance as Affected by Location.

The cost and difficulty of maintaining track and road bed may be greatly affected by the general characteristics and local details of the selected route, and all such conditions should receive careful consideration during the location of the route.

The greatest differences may exist, even between the two sides of the same valley, as one side may be subject to contingencies of drifting snow, slides, cloud bursts, stream encroachments or " "washouts," from which the other side is wholly free. Conditions of greater shade, due to forest or bluffs, may cause longer duration of snow, frost and moisture, or local peculiarities of soil, and the character and number of lateral streams to be crossed may all contribute towards the increased cost of maintenance.

Additions to cost of maintenance arising from faulty details of "construction," may not be properly considered in connection with the subject of "Location," unless resulting directly or indirectly from the character of the location, such as unnecessary increase in number and length of bridges: grade crossings in lieu of possible under or over crossings, faulty arrangements of grades, affecting yard and station expenses, and other items of like character.

All additions to operating expenses, arising from such causes, should be included in equations of alternate routes, capitalizing same if necessary, at the ruling rate of interest.

Note.—The table of Velocity Heads and the economic values given for "Distance," "Curvature" and "Rise and Fall" are derived from Wellington's "Economic Theory of Location;" the values have been capitalized at 6 per cent.

Surveys and Construction.

Surveys.

The railway company will furnish instruments, transportation, camp equipage and subsistence while parties are employed in the field. Each individual will provide himself with all personal articles, such as drawing instruments, clothing, blankets, etc.

All survey lines diverging from any constructed line must be connected with it by measurement, so that the initial point can be located upon the map of such constructed line.

Stations will be uniformly 100 ft. long each, and numbered consecutively. It is not necessary to set takes at each station in all cases on preliminary lines; this may be left to the discretion of the chief of the party. Mark stakes on alternate lines with distinguishing letter A, B, C, etc. Mark stakes on located lines "L." Mark point of curvature "P. C." or "P. S.;" point of tangency "P. T." on the stakes of the beginning and end of all curves. Mark stakes at the "P. C." or "P. S." with the degree and direction of the curve.

Ties must be secured to all township and subdivision lines whenever crossed. Give station number of intersection, angle of intersection, distance along the line to the nearest corner or quarter corner. Whenever possible, make the intersection by running through between the two corners.

When line is located through villages or towns, take necessary measurements, tieing the center line to the plats, and secure tracings of the town plats as contained in the county register's office, with all dates and certificates contained in original, and send these copies to the office of the Chief Engineer.

Tie in all property and land lines, and locate all buildings that are near the line.

Check all angles by needle reading, or by doubling the angle or both. Check all measurements by chain or tape. Check chains frequently by steel tape or level rod.

Keep all instruments in proper condition and good adjustment.

Always establish a substantial and permanent bench at the initial point of all surveys, and at short intervals along the line. Use the sea level datum, and if one has to be assumed, ascertain its relation with the standard datum at the first opportunity, and correct all elevations accordingly.

All level notes must be checked at the end of each day's work by adding the backsights and the foresights, and ascertaining the difference.

Maps, Profiles and Records.

Maps of located lines, made in the field, will be usually drawn to a scale of 1 in. to 800 ft.; in broken and difficult localities, 1 in. to 400 ft. General maps to be sent to the office of the Chief Engineer may be drawn to a scale of 1 in. to 4,000 ft., etc. The maps will be made in conformity with the standard specimen sheets furnished from the office of Chief Engineer.

Maps, plans and profiles are to be drawn with the top of the paper to northward or westward, and the letters and figures are to be right side up toward the top or toward the left hand side of the paper, and must otherwise conform with the specimen profiles.

Maps and profiles should give names of all rivers and streams, names of owners or occupants of houses, ranches, or farms passed by the line, etc. Put on all the information necessary to enable another person to fully identify any locality. Be certain to note on profile all extreme high or extreme low water marks, wherever found, even if only approximate. The meridian should be drawn on all maps, both true and magnetic, when both are known.

On each drawing of any kind, put name of engineer, initia' of draftsman, date, place, etc. On both ends of the outside of the paper, give the title in full of the map, plan, sketch or profile.

Tracings of maps and profiles of all lines run must be sent to the office of the Chief Engineer, distinctly marked with the name of the line, streams, and all other information necessary to identify the locality.

Tracings of located lines showing government and property lines, streams and date of commencing and completing survey, must be made and sent promptly to the office of Chief Engineer, as soon as each section of 20 miles has been finally located, for the purpose of filing map of definite location in the land office.

All changes of line made after the map of definite location has been filed in the general land office must be approved by the engineer in charge before being adopted, and as soon as made, reported to the Chief Engineer with a tracing of new and old line, and tracing profile of the part altered.

Topography on general maps should be given for a distance of 1,500 ft. on each side of the center line, and further when necessary to show important features. In order to facilitate plotting contour topography, the notes should give distances of contours from the center line.

All courses of line must be given in reference to the true meridian, and for that purpose an observation must be taken upon starting the survey and the true course recorded in the field books, as the work progresses. An additional observation should be taken for the correction of meridianal convergency whenever the extent of the survey shall attain a departure of one-half degree of longitude.

Curves and bearings of tangents shall be noted on the maps and profiles in the manner shown on the samples furnished. When practicable give true bearings instead of magnetic. State which is given.

To avoid cumulative errors, when platting lines, all angles must be laid off from some standard bearing, using the calculated course for this purpose. This can be done best by laying off any convenient bearing in the general direction of the survey and transferring all angles turned from this line by parallel rules or triangles, to the last point scaled. This will, on located lines, require all tangents to be calculated from intersection to intersection.

Indicate on the map, or otherwise, the width and extent of extra right of way necessary for stations, side tracks, "Ys," borrow pits, etc., on the line of the road.

Profiles, when completed, shall contain all the information called for on the sample copy furnished from the office of Chief Engineer, and arranged in the manner shown thereon. The original profiles must be made on the regular profile paper. Tracings must be made in sections of 20 miles from the original profile, and sent to the office of Division Engineer, from which the necessary blue-prints will be made for contractors. Intersecting grades are to be connected by vertical curves having a rate of change of grade per station of 0.05 ft., except on summit curves where the rate of change may be 0.1 ft. or more per station.

Profiles should show alinement drawn in red near the bottom of the paper. The direction of the curve is shown by drawing the radial lines to an intersection on their proper side, at the middle of the curve.

Progress profiles will be sent each month to the Chief Engineer's office, properly colored to show all work done to and included in the last estimate, on the part of the road in charge of the engineer. These profiles must show all work done during the preceding month; not only grading, but details of bridges and culverts built, with their exact location; description and location of all buildings, or structures of any kind, wells dug, main track, sidings, or "Ys" laid, etc. The depth that piles are driven below the surface of the ground should be indicated by dotted lines, showing the point of lowest pile in bent; the mud sills of trestles should be shown by a short heavy line, and on steep side hills the elevation of each mud sill should be indicated in the same way. Prints from "Solar" negatives of tracing profiles in the Chief Engineer's office will be furnished for progress profiles. The completed profiles will be retained in the office of the Division Engineer at the close of the work.

The standard progress colors are as follows:

January....Chrome yellow.	July ..... Sepia.
February ..... Carmine.	August .... Emerald green.
March .....Payne's gray.	September .... Cobalt blue
April .....Deep chrome.	October ..... Vermilion.
May ..... Prussian blue.	November ..... Indian red.
June .....Burnt Sienna.	December ..... Sap green.

Track profiles must be prepared in all cases when necessary for the guidance of the contractor, showing, in addition to the ordinary alinement notes of the profile, the number and length of rails to each tangent, the number of long and short rails in each curve, and the ordinates to which they are to be curved.

Field books must indicate each day's work, giving date. The fly leaf of each book must show in ink the name of the branch or division, nature of survey, kind of notes, name or engineer, name of instrumentman, or topographer, and the terminal points contained in the book. See that all subjects contained therein are properly indexed and that all notes of adopted or abandoned lines are properly marked as such. Have notes so plain that they may be understood by any one.

The original field notes should be sent in to the general office when the survey is completed. In case the original notes are not in good condition have them copied in new book, giving a revised and complete record of alinement, levels, topography, right of way notes, and other data pertaining to the line.

Diaries will be furnished to engineers and instrument men on construction. Details of each day's work must be entered, giving dates of staking out work, commencement and completion of work on excavation, bridges and buildings; rise and fall of streams, and other data of future value. These diaries must be returned to the Assistant Engineer at the close of the work.

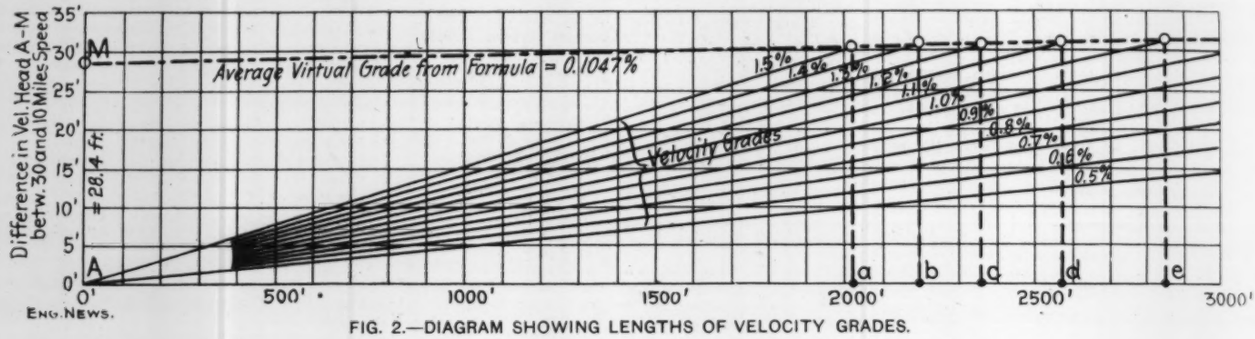


FIG. 2.—DIAGRAM SHOWING LENGTHS OF VELOCITY GRADES.

Formula for Determining the Average Virtual Grade.

$$S_v = \frac{1}{20}\left\{\frac{T}{W} - R\right\}. \quad (1)$$

S_v = average virtual grade expressed in per cent.
T = mean cylinder tractive power in lbs. for given initial and terminal speed.
W = weight of train in tons of 2,000 lbs., including engine and tender.
R = mean train resistance in lbs. per ton of train.

Note.—The maximum virtual grade for a given trainload (W) is found by inserting in above formula the train resistance (R) and the cylinder tractive power (T) for minimum speed (10 miles per hour).

Example: In above diagram is shown the length of velocity grades for engine Class D 3 Mogul, pulling a train weighing 1,250 tons (including engine and tender) for an initial speed of 30 miles and a terminal speed of 10 miles per hour.

The difference in velocity heads (A M) taken from Table of Velocity Heads = 31.95 − 3.55 = 28.4 ft.

The average virtual grade (S_v) is calculated from formula:

$$S_v = \frac{1}{20}\left\{\frac{T}{W} - R\right\} = \frac{1}{20}\left\{\frac{11{,}743}{1{,}250} - 7.3\right\} = 0.1047\%.$$

T = 11,743, taken from table of mean cylinder tractive power.
R = 7.3, taken from table of mean train resistance.

The length of velocity grades from A to a, b, c, d, e, etc., is found by construction, as shown in the above diagram, or may be found by calculation from the formula

$$l = \frac{d}{S - S_v},$$ in which l = length in stations of 100 ft.;

d = difference in velocity heads for the given initial and terminal speed; S = actual grade in per cent., and S_v = virtual grade, as found from formula (1). The maximum virtual grade of the above example is

$$= \frac{1}{20}\left\{\frac{17{,}850}{1{,}250} - 4.7\right\} = 0.470\%.$$

Table of Mean Train Resistance in Pounds per Ton for Loaded Cars.

Speed—Initial.	Speed—Terminal.	R.
45	10	10.6
40	10	9.4
35	10	8.3
30	10	7.3
25	10	6.5
20	10	5.8
15	10	5.2
10	10	4.7

Table of Velocity Heads.

(Vel. head = 0.0355 v^2.)
v = speed in miles per hr.

Speed in miles pr hr.	Velocity head in ft.	Speed in miles pr hr.	Velocity head in ft.
10	3.55	28	27.83
11	4.30	29	29.86
12	5.11	30	31.95
13	6.00	31	34.12
14	6.96	32	36.35
15	7.99	33	38.66
16	9.09	34	41.04
17	10.26	35	43.49
18	11.50	36	46.01
19	12.82	37	48.60
20	14.20	38	51.26
21	15.67	39	54.00
22	17.19	40	56.80
23	18.79	41	59.68
24	20.46	42	62.62
25	22.20	43	65.64
26	24.00	44	68.73
27	25.88	45	71.89

Right of Way.

As soon as the construction of a line has been ordered the division Engineer will issue the necessary instructions for securing the right of way, which will be uniformly 100 ft. in width, except where additional land is required for station grounds, borrow pits, wide slopes, or other purposes.

The right of way should be secured as rapidly as possible, contracts for same being taken and forwarded immediately to Division Engineer's office, where deeds and vouchers will be made.

The right of way agent will be under the orders of the Division Engineer, but will consult freely with the Assistant Engineer in charge of the line, and will make all agreements as to fences, cattle guards, road crossings, ditches, etc., subject to his approval.

The description of irregular tracts which are acquired by the company will be by metes and bounds, obtained by actual survey. The description of right of way through government subdivisions will be made in the following form:

A strip, piece or parcel of land one hundred feet in width, situated in the northwest quarter of the northwest quarter of section 10, in township two north, range one west (S. 10, T. 2 N., R. 1 W.), Madison county, Montana, and having for its boundaries two lines that are parallel with and equidistant from the center line of the railroad of the.....Railway Company, as the same is now located (and constructed). For a more particular description, reference may be had to the plat drawn upon and made a part of this deed.

The description of lots in platted tracts should be in the following form:

Lot seven (7), block six (6), in Smith's addition to Helena, Lewis and Clarke county, Montana, according to the recorded plat thereof.

All plats drawn upon deeds should give ties to the government survey points or to some fixed and indestructible points, so that the land can be located from the description and the plat.

As soon as the right of way has been definitely secured, plats of the same will be prepared in Division Engineer's office, conforming to standard scale and plan furnished by Chief Engineer, to whom they will be forwarded when completed, accompanied by the deeds.

Estimates.

A careful estimate must be made showing the probable cost of every located line and of every structure or special work upon which a report is ordered. Great precaution must be taken to include everything necessary to complete the work ready for operation or use. This applies to work to be done by both the Construction and the Engineering Departments.

In case it is necessary to make the estimate before the exact quantities are determined, it must be replaced by another whenever the data can be obtained.

In monthly and partial estimates, make returns of grading to nearest ten yards, and masonry to nearest five yards.

Monthly statement (form 106), showing expenditures to date and comparison with the preliminary estimate, will be prepared by Assistant Engineer at the close of each month and sent to Division Engineer, who will note and forward to the Chief Engineer.

No estimate or statement of quantities will be given to contractors or sub-contractors not bearing the certificate of the Assistant Engineer.

The standard record book, form No. 62, of the Company, will be furnished each engineer in charge of a residency. The notes are to be written in ink, when final. The record should contain cross-section notes, and all other data pertaining to calculation of quantities, classification in detail, ground and grade elevations, alinement, material or labor accounts; and the data for every item embraced in the final estimate. A summary will be made giving the final estimate in sections of one mile, conforming to the mile-posts of the branch or division. The record must be kept up, as far as possible, while work is in progress, and must be turned in to the Assistant Engineer at the close of the work, and finally checked in the office of the Division Engineer.

General.

The plans and work of the Company are its private property, and must not be imparted to any one. Reports must be made to the immediate superior of the engineer or employee, and to no one else.

The rates of pay of all employees will be fixed by the Chief Engineer, and no change of rate so fixed shall be made without his authority first obtained.

Damage, destruction or loss of property of the Company through carelessness or wilfullness, must be made good by the individual at fault.

Engineers in immediate charge of parties are responsible for all Company property in their charge, and are expected to prevent extravagance and waste in the use of supplies of all kinds furnished by the Company.

Locating and resident engineers will forward a weekly report to their superior officers, reporting progress of work and all other general items of interest, pertaining to the work. This will be accompanied by force report, form 138.

All engineers must make themselves familiar with the conditions of the contracts and specifications for work under their charge; they should attend to any reasonable request of contractors, furnish them heights, lines, stakes, plans, etc., whenever necessary, and in general do all things requisite to enable contractors to work to advantage and without delay.

During construction each line will be divided into residencies of convenient length, as directed by Division Engineer, each in charge of a Resident Engineer, and provided with such assistants, camp equipage, transportation, and other outfit as may be necessary.

The nature of the work and the various facilities must be carefully considered as soon as the construction is ordered, so that competitive proposals may be obtained for everything that will be required.

Each Assistant Engineer in charge of a line will submit, for approval of the Division Engineer, a list of all buildings, sidings, Ys, etc., with proposed location of same, required on his work. The Division Engineer should submit all proposed plans for station or terminal facilities to the proper officials of the Operating Department for criticism, and their suggestions must receive careful consideration.

The arrangement of all stations and terminals and the appurtenant tracks, the location of water tanks, and all matters having a bearing upon the operation of any line, should also be submitted for criticism before construction.

Engineers must prosecute their work economically and will be expected to work to the estimates closely.

All structures will be built in accordance with the standard plans of the Company, and no deviation will be made from same except by authority of the Chief Engineer. Standard plans will be furnished from Chief Engineer's office, and at the close of each piece of work all that have been used on same, by engineers or contractors, will be returned to Division Engineer.

The usual classification of grading will be earth, loose rock and solid rock. If cemented gravel or soft rock in place or other distinctive material exists in considerable quantities, the fact must be reported to the Chief Engineer in order that it may have a proper classification assigned to it.

In staking out grading, have number of station marked on face of center stake, and cut or fill on its back. On slope stakes have cut or fill marked on the face, and number of station on the back.

Banks must be made full and regular. Care must be taken to avoid sags between stations. The roadbed throughout must conform strictly to the standard plan.

In regions swept by strong winds, where the snow-fall is liable to be great and drifting to occur, all structures will be put on that side of the track opposite the prevailing winds. Usually this will be the southerly side, and station buildings, water stations, switch stands, and every kind of structure that can cause the formation of drifts, will be put on that side. Sidings and spur tracks should be put on the same side, where practicable.

When embankments are rip-rapped to protect them from action of water, that part of embankment upon which the rip-rap is placed should generally be made with slope not less than two to one. If the embankment has been finished at a steeper slope, the rip-rap should usually be so placed that its exterior slope shall be two to one.

Surface ditches must be laid out with great care to prevent water from running down the slope of cut, or against embankments, or being carried to any point where it can act injuriously upon any part of the work. The ditches should be made of ample size; not less than one foot wide at the bottom in any case; and if the area is considerable from which water may accumulate, they should be made two feet wide or more at the bottom. Material excavated in their construction should usually be thrown on the side toward the cut. In few matters is there more opportunity to show good judgment than in judiciously disposing of surface water about cuts. All cuts must have surface ditches and thorough drainage.

In turning streams care must be taken to make embankments across old channels strong enough to resist the action of currents. In such cases the width of the embankment should usually be made not less than ten (10) feet from the center line on the side against which the current will act, with slope of two to one. In cases of soft, spongy, or sliding material, this width should be increased on the exposed side. It should be borne in mind that it is less costly to build an embankment with excess of strength at first, than to have it washed out and be compelled to rebuild it.

In turning rapid, turbulent streams, take special and full precautions to prevent the new embankments from being washed away while building before they are high and strong enough for effectual resistance.

In building culverts and other waterways of perishable materials, ample allowance in size must be made for reconstructing them at a future time of durable materials. Wherever practicable iron culvert pipes should be hauled ahead and placed in position before the embankments are completed.

Vitrified tile pipe of double strength will be used under road crossings.

In building permanent box culverts of stone or brick, the smallest opening to be allowed is 9 sq. ft., clear of all obstructions. The height of the opening of a culvert should never be less than its width. The greatest care should be taken to secure the foundations of all culverts and water conduits.

Stream diversions, even when of considerable magnitude, usually prove much cheaper in first cost and also in subsequent maintenance than the bridging otherwise required, particularly when the excavated material is used in embankments.

The natural "scour" of the stream may sometimes be relied upon to widen channel excavations of small original cross-section, but in all cases due precautions must be taken to insure final cross-sections of full and ample proportions.

Pile and trestle bridges, not required in part or in whole for water-way, are too frequently constructed in order to save time or to avoid real or supposed difficulties in forming the embankments. The maintenance cost of such bridges is many times in excess of that of embankments of equal first cost, and no bridges of this character should be built unless the cost of the embankments otherwise necessary exceeds both the first cost of such bridges and the subsequent cost of filling same by train or otherwise.

Thorough drainage is a maxim to be impressed on the mind and practice of every one engaged in construction, and engineers must beware of being deceived or misled in so-called "rainless districts," for experience proves that sometimes (perhaps at long intervals), most destructive and uncontrollable floods occur in such localities.

Top of bridge stringers will be set 0.25 ft. above regular profile grade, and regular grade changed about 100 ft. to meet it. This will apply in all cases, unless otherwise ordered.

In the construction of pile and trestle bridges a competent inspector should be retained, whose duty it shall be to keep a record of all piles driven. The inspector's record must show length of piles, depth to which each pile is driven, sinking in inches by the last three blows of the hammer, weight of hammer, and fall in feet of same, and amount of piles cut off.

Engineers should endeavor to secure, wherever practicable, at reasonable expense, undergrade or overhead highway crossings. Bridges and culverts can frequently be utilized at slight expense for undergrade crossings for stock by making necessary openings in right of way fence.

Before the completion of the work, all construction material left over and scattered along the line must be picked up and returned to the material yard. Refuse will be burned or otherwise disposed of.

A COMMERCIAL INSTITUTE, modeled after the Higher Commercial Institute of Antwerp, is proposed by the National Business League Association of New York. The purpose of the school would be to train young Americans for consular and foreign commercial service, with two classes of students. The "regular" students would attend all lectures with the purpose of obtaining a diploma at the end of two years; the "free" students will only take such course as may benefit them in a special commercial career. The course would include "correspondence" in German, French and English, as obligatory, and one other language optional; political economy, international commercial law, customs regulations, geographical and economic conditions of foreign countries, relative values of raw materials, different sources of supply, etc. The students would also be encouraged to take a close interest in political events of the day as affecting commercial interests. The student would pay $50 the first year and $60 the second year.

COAL MINES IN SHANTUNG, CHINA, are reported upon briefly by Consul John Fowler, of Chefoo. The report is based upon an examination made by Mr. Earle D Sims, of Tai-an-fu, the capital of the department of that name. This report is from only one department of Shantung, containing 2,000,000 inhabitants out of 29,000,000 for the whole province. Coal mines are reported with shafts from 60 to 242 ft. deep, showing coal veins from 21 ins. to over 5 ft. thick. One of the best-known mines is at Hsi-Ku-Chung-Tswang, about 27 miles south of Tai-an-fu; it has three shafts of 100, 90 and 82 ft. in depth, opening up a vein 5 ft. 3 ins. thick and exposed over an area 900 ft. square. About 60 miles northeast of Tai-an-fu is a new mine, with a 242-ft. shaft and a vein 5 ft. 2 ins. thick. The quality and character of the coal is not referred to in the report; but it has been mined by very primitive methods for an unknown time. Mr. Sims also reports finding gold, silver and lead ore. Shantung Province is on the coast, and includes the peninsula forming the south boundary of the Gulf of Pechili.

A TEMPORARY SUPPLEMENTARY WATER SUPPLY for Newark, N. J., is provided for by two contracts authorized by the Street and Water Commissioners on April 13. One awards a contract for driven wells at the old pumping station in Belleville to Mr. A. J. Conolly. The other contract is with the East Jersey Water Co. The company agrees to construct a pipe line from Little Falls to the Belleville reservoir by Dec. 1, 1899, and to deliver water to Newark from that date to Sept. 24, 1900, when Newark will have the full supply of 50,000,000 gallons a day from the Pequannock River, instead of 27,500,000 gallons, as now. The city is to pay 4% interest on the construction of the pipe line and accessories during half the time taken for construction and up to Dec. 1, 1899. For water used the city will repay the company in water later on.

A STANDPIPE TEST was made at the Manhattan Life Building, New York city, on April 15, by Chief Hugh Bonner, of the New York Fire Department. The roof of the Manhattan Life Building is 250 ft. above Broadway, and is surmounted by a dome, whose gallery is 340 ft. above the street. The base of the flagstaff, which is 30 ft. high, is 10 ft. above the gallery of the dome. An engine of the department was used in making the first test. Water was forced through a standpipe to the cradle of the dome, throwing a stream about 70 ft. above the top of the flagstaff. A 1⅝-in. nozzle was used. The pressure at the nozzle was 50 lbs., and at the engine 290 lbs. The height of the stream was about 450 ft. A 1¼-in. nozzle was employed in making the second test, and while the stream displayed a little more life than in the previous test, there appeared to be little difference in utility. In the third test the house plant, which is designed with more especial regard to volume, was used, and it exhibited no superiority over the department engine. A 1⅜-in. nozzle was employed, and the pressure at the nozzle was 25 lbs., with a pressure at the stationary pumping engine of 290 lbs. Six streams were also thrown from the upper floors into the court of the building with the aid of the house plant. The tests were witnessed by a large number of insurance men. After the conclusion of the tests Chief Bonner said:

So far as the department is concerned, the tests were entirely satisfactory. They justified my belief that if all of the high buildings were equipped with an efficient standpipe system, a fire like that in the Home Life Building last December (Eng. News, Dec. 8, 1898,) would be rendered impossible. Of course, when we are compelled to depend upon hose, which must be carried up through the building, we cannot be so successful in fighting a fire which becomes lodged in the upper stories of a high structure. The tests made to-day in the Manhattan Building were satisfactory, and will be followed by tests in some of the other high buildings.

AN ELECTRIC HEADLIGHT for locomotives, which throws a vertical beam of light, as well as the horizontal beam projected in front of the train, has been invented by Mr. Edgar A. Edwards, of Cincinnati, O., and has been tried on an engine running between Cincinnati and Indianapolis. In front of the headlight is a deflector inclined at an angle of 45°, which intercepts a portion of the rays and throws a vertical beam of light. A similar arrangement can be used by the searchlights of steamers. The device is being manufactured and introduced by the Edwards Railway Electric Light Co., of Cincinnati, O., with Western offices at 1330 Monadnock Block, Chicago.

COUNTY BICYCLE PATHS in Pennsylvania are authorized by a bill just signed by the governor. The new law provides that on the petition of 25 resident freeholders, who must be wheelmen, the court of any county shall appoint three wheelmen as Side Path Commissioners, to serve without pay, other than necessary expenses. The commission may levy such a tax as it sees fit, not exceeding $1 upon each wheel in the county, the proceeds to be used for constructing side paths not less than 3 nor more than 6 ft. wide between the roadway proper and the private property line.

A MACHINE FOR WORKING NEW ZEALAND FLAX is wanted, and in 1895 the Department of Agriculture of New Zealand offered a prize of £1,750 for a machine or process for dressing this flax that would be an improvement on those in use and materially reduce the cost and improve the product, or increase the quantity of dressed fiber. A bonus of £250 was offered at the same time for a process for utilizing the waste products of the hemp. U. S. Consul F. Dillingham, of Auckland, says that while the time has lapsed, as fixed in the original invitation, he is semi-officially informed that any one furnishing a really satisfactory machine could make terms equivalent to the bonus. This New Zealand hemp (phormium tenax) now takes 7 tons of raw to make one ton of

dressed fiber; but up to this time no machine or process has been found which seems to comply with the requirements of the committee appointed by the Department of Agriculture.

ALUMINUM IN BRASS CASTING is commented on by the "Aluminum World." For making metal harness trimmings, Mr. Edward Zust, of Newark, N. J., finds that the addition of the right proportion of aluminum to the brass acts beneficially, unless the brass is to be dipped in acid; in dipped work the use of aluminum is not advised. The Brabson Bros., of Newark, make hardware specialties; they put the aluminum in the brass just before pouring, and stir it in. The result is "a sharper casting with a firmer texture." The "World" says that founders usually use too much aluminum; a piece as big as a pea in 100 lbs. of brass will beneficially affect the metal. The Patton Mfg. Co., of Columbus, Q., put only 1% of aluminum in No. 3 government bronze; and by so doing they raised the tensile strength from 47,000 to 53,000 lbs. per sq. in. The best way to introduce the aluminum into brass is in the form of aluminized zinc, which has a standard mixture of 10% aluminum and 90% zinc.

A NEW CIRCULAR AUTOMATIC DIVIDING ENGINE has been constructed for Mr. George L. Buff, instrument maker, of Boston, Mass., and successor to the old firm of Buff & Berger. This machine is constructed entirely of steel and iron; thus gaining the equal and small coefficient of expansion characterizing these metals. The bearings are specially hardened steel in malleable iron sockets. The iron circle is 28.65-in. diameter, with 1,80) teeth; and the original graduation, on a band of inlaid silver, was made by a peculiarly accurate electric method with the aid of a pair of high-power microscopes. The teeth were cut in three separate operations; the first cut being absolute within two seconds of arc, and the third producing the fully developed tooth. A specially designed cutter was then set in and run continuously for over a month, and the actual worm was finally substituted and run day and night for a time in an even temperature, establishing the essential evenness of motion. The automatic movement is the development of 35 years' experience, and operates without springs or weights. Mr. Buff is now planning a still larger engine on the same design, which is to exceed in size any practical graduating engine ever built.

BOOK REVIEWS.

NORWICH UNIVERSITY.—Her history; her graduates; her roll of honor. Compiled by William A. Ellis, B. S., Concord, N. H. The Rumford Press. Cloth, 6 x 9 ins.; pp. 624. Illustrated. Price, $3.50. Address Wm. A. Ellis, Northfield, Vt.

The military academy, out of which grew Norwich University, was founded at Norwich, Vt., in 1819, by Capt. Alden Partridge, who graduated from West Point in 1806. In 1825 the academy was moved to Middletown, Conn., but in 1829 it moved back to Norwich with his apparatus and equipment; and in 1866 the University was established at Northfield, Va., where it still flourishes. Capt. Alden Partridge was the pioneer in recognizing the need of a military school for the young men of the country outside of the Academy at West Point, but similar in its methods of teaching. His academy became popular, and the long "roll of honor" given in this volume contains the names of very many men famous in the military, naval and civil records of the United States. Among soldiers we find Generals Grenville M. Dodge, F. W. Lander, R. H. Milroy, T. B. Ransom and Capt. George H. Derby, of "John Phoenix" fame. Of sailors we have Admiral George Dewey and Rear Admirals H. Paulding, C. S. Boggs, C. C. and E. W. Carpenter. Statesmen are represented by Horatio Seymour, Gideon Welles, Theo. Sedgewick and W. P. Kellogg; and among other engineers we find Monoure Robinson, Moses Lane and Ed. F. Johnson. These are a few only of the men who, starting at this academy, have achieved fame in some profession or occupation.

ISTHMUS OF PANAMA AND NICARAGUA CANAL ROUTES, ETC.—Compiled by Thomas Wright Hurst from Various Authors. Cloth, 4to.; pp. 98; 2 maps. $2.

This book is a compilation of many articles written by the author and others for technical papers and the daily press, together with extracts from various books, reports and the proceedings of scientific societies, regarding the different routes which have been suggested for an interoceanic canal. It contains much interesting matter, and goes into some detail respecting the history of the early settlements and explorations of Central America. The author has made the subject a "hobby" for some years past, and has ransacked old and modern literature for his purpose, but the material might have been arranged and presented to much better advantage with more editing and some summarising of the general results of the investigations.

The Panama, Nicaragua, San Blas, Tehuantepec (ship railway) and Darien routes are discussed, and the latter is strongly advocated, about 60 pages being devoted to articles and engineer's reports thereon. The former include articles from Engineering News, and the latter include the reports upon the Darien projects in which Sir Charles Fox, Mr. Thomas Brassey, Mr. Lionel Gisborne, and other engineers, were interested between 1850 and 1860. The Darien route described in our issue of March 14, 1895, called for a tunnel through the Cordilleras, but Mr. Hurst is of the opinion that a low-summit route can be obtained. The book concludes with the suggestion that a government survey should be made of the short route advocated by Mr. Hurst, crossing the Isthmus close to the mainland of South America, starting at Caledonia Bay or Port Escoces, on the Atlantic side, and running southwest to the head of the Gulf of San Miguel, which gulf extends inland for some distance. Part of the route would be an enlargement of the Savana River, and the total length is given as 33 miles, as noted in a letter from Mr. Hurst, in our issue of April 6.

RAILWAY BLOCK SIGNALING.—The Principles of Train Signaling and Apparatus for Ensuring Safety.—By James Pigg, A. I. E. E. London. Biggs & Co., 140 Salisbury Court. Cloth. 8vo. pp. 387; illustrations, 147 cuts in the text. Price, $1.80 (7½ shillings).

This book treats only of the history and practice of signaling on British railways. The general principles and early history of block signaling are first discussed, and are followed by the old (1861) and new (1896) standard codes used on British railways, with a discussion or analysis of the various provisions of the codes. Train signals, hand signals, and fog signalling are included, with a description of the various forms of signals and their uses. In regard to block signaling proper a large proportion of the book is devoted to detailed descriptions of various forms of signaling instruments, and the lay-out of individual installations under different conditions, as at junctions, drawbridges, and complicated track systems. The train-staff and train-tablet systems are described, as well as different forms of rail-contact instruments for the auto-manual system, the latter including instruments of Mr. Pigg's invention.

The author expresses the opinion that signaling will in future be more and more automatic, but by this he means the use of automatic instruments for the auto-manual system, and not the automatic system (in name and in fact) as used in this country. The only reference to purely automatic signaling is a description of the Timmis system used on the Liverpool electric elevated railway. In regard to methods of giving signals in the engine cabs Mr. Pigg says that while the general adoption of such substitutes for the present outdoor mechanical signals would constitute a revolution in signaling, it would, in his opinion, be a considerable advance toward complete efficiency, and could not fail to be more economical than the present methods of signaling.

The book is well printed in large type, but the majority of the illustrations are so bad and so illegible that we wonder the publishers or the author allowed them to be used. The index is poor and unsystematic.

THE LOCOMOTIVE UP TO DATE.—By Charles McShane. Chicago: Griffin & Winters. Cloth.; 8vo.; pp. 712; illustrations, 380. $2.50.

This book is intended chiefly for the locomotive engineer or engineman, but will also be useful to many mechanical engineers. It is peculiar in that it describes and illustrates a large number of styles and makes of various devices. Thus, we find a dozen or more injectors, and seven valve gears (including the link, Walschaert, Joy and Lewis). The book is, however, of a very patchwork character, the descriptions of some devices being furnished by the inventors or makers, or taken from the technical papers and inserted with little or no editing. There are also certain patented devices described from the patents, without any information being given as to whether these devices have been actually made or used. There is little attempt to compare the merits of different devices for the same work. Under boiler checks, for instance, different kinds are shown, including an inside check valve, but nothing is said as to the reason why it is desirable to put the check valve inside the boiler. The book is brought well "up to date," as its title implies, and we even find a description of the De Wallace train-order signal device for the cab, recently described in our columns.

The work commences with a few pages on the history of the locomotive, and an article by Mr. Angus Sinclair (from the "Pall Mall Gazette") on the relation of the locomotive to civilization. The descriptions of valves and valve gears and methods of setting valves occupy some 200 pages, and the injectors, indicators, lubricators, gages, safety valves and other fittings, about 300 pages more. Then come a few pages on the practical work of locating blows and pounds, setting up wedges, starting the engine, etc. About 75 pages are devoted to the compound locomotive, and ten types built in this country are fully described, the descriptions being furnished by the several builders.

The methods of making road repairs in case of breakdowns occupy about 20 pages, and then follow descriptions of exhaust nozzles, petticoat pipes, spark arresters, and blow-off devices—the latter including the Hornish blow-off, recently described in our columns. Singularly enough no mention is made of boiler or firebox construction. Descriptions and illustrations of a number of modern engines (including the Baltimore & Ohio R. R. electric locomotive), then follow, with records of some fast runs. Then comes general machine shop work and machine work (or the handling of machine tools), occupying about 75 pages, and the metric system, compressed-air locomotives, and various compressed-air track sanding devices come in for a share of attention. These are followed by an article on air brakes by Mr. C. B. Conger, which, with brake instructions and some miscellantous matter, occupies about 90 pages, and concludes the book.

The book is, as has been said, almost entirely descriptive, and not critical or analytical. It would be greatly improved by a more systematic arrangement and some good editing, and by subdivision into chapters. It is well printed in large clear type, and most of the numerous illustrations (both line and half-tone engravings) are clear and distinct. The index is poor and unnecessarily long.

DIE INGENIEURTECHNIK IM ALTERTHUM.—von Curt Merckel, Ingenieur. 1899. Berlin: Julius Springer. Boards, 10¼ x 7½ ins.; pp. 658; 261 illustrations in the text and one map. 20 marks ($7).

The author has here gathered together a wealth of most interesting matter relating to the earliest practice of the art of the engineer, among the Babylonians, Assyrians, Egyptians, Persians, Chinese, East Indians, Greeks and Romans. He treats of the tools and machines employed, and of the materials of construction used, and discusses the methods most probably resorted to in moving and erecting the enormous masses of stone still standing as evidence of the power and resources of the ancient engineer. In separate chapters, well illustrated and each concluding with a very full bibliography of sources of information, the author takes up irrigation, road construction, bridge building, harbors, the building of cities and their water supply by means of aqueducts and reservoirs.

The irrigation of land and the storage of the flood waters of rivers seem to have first called for engineering construction of considerable magnitude. In Egypt, work of this character appears to have been in existence on the very margin of the historic period; and in China, artificial water-ways, mainly employed for transportation purposes, were in use in 1121 B. C. As proof that the engineer was at work even in the very remote periods of our history, we have the so-called tunnel of Nimrud, driven for nearly one mile through the solid rock, and ascribed by Layard to the second Assyrian dynasty; and about 396 B. C. the Albanian Lake was drained by another rock-tunnel about 4,000 ft. long. While excellent roads existed among the Babylonians and Assyrians, and even among the early Chinese, the construction of highways received its great impetus from the military ambition of the Romans, and a wonderful system of roads was constructed aggregating about 6,569 English miles in length, and spreading over Italy, Africa, Spain and England. The author describes the main routes followed by these old roads, under the above four groups, and shows how they were built. As these great highways implied means for crossing streams, it is natural that under the Romans bridge construction was greatly developed; and the author gives us a large number of such structures, many of massive proportions and graceful design. Under this head arch construction is discussed for all ages down to Assyria.

Ship-building and harbors to shelter them seem to have originated with the Phoenicians, the earliest sea-rovers; and we have a long chapter devoted to the harbors of Tyre, of ancient Greece and of Rome. Under the head of civil construction, Mr. Merckel discusses the laying out of cities, their protection by walls and fortified places, the city gates, public places, drainage, etc. Water-supply begins with the reservoirs, canals and tunnels of old Assyria, and passes on to its fuller development in the wonderful aqueducts of Rome, and the aqueducts of Roman construction in other parts of Europe. The Roman system is very exhaustively treated, and each one of the fourteen aqueducts in existence in 565 A. D. is described in full, with views, cross-sections, lead water-pipe, etc. The oldest aqueduct, that named after Appius Claudius, the builder of the Appian Way, was built in 311 B. C., and is 10.3 miles long; heads 203.4 ft. above sea-level, and delivered its water in the city of Rome at an elevation of 176 ft. above the sea.

In a closing chapter the author discusses the status of the builder or engineer among the ancients, and gives him an honorable position. The earliest mention of men of this profession is found in the records of Egypt and China; and among the first we have Heka, or Hapu, mentioned as a "Masterbuilder" in the reign of King Snephru. Chinese literature speaks of an engineer, Pokoen by name, who flourished in 2300 B. C. In early Grecian history we have the more or less mythological personages of Euryalos, Hyperbios, Thrason, Daedalos and Talus, all noted for some engineering exploit more or less remarkable, or as builders in wood. The first Greek engineer on record as ranking among ordinary mortals was Eupalinos, the builder of the harbor of Samos, which was in existence in 540 B. C. From this period onward a long list of ancient engineers is given, chiefly in connection with Roman construction. This remarkable book is made more valuable by an excellent index and a general summary of the more noted engineering works under the Greeks and Romans.